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OHMSETT (Oil and Hazardous Materials Simulated Environmental Test Tank) Test Series 77: Global Oil Recovery Skimmer, Veegarm Skimming Arm Kebab 600, Wylie Skimmer and the Skim-Pak Cluster

Mason and Hanger-Silas Mason Co., Inc.
Leonardo, NJ

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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This report covers the performance testing of five oil spill recovery devices at the Oil and Hazardous Materials Simulated Environmental Test Tank in Leonardo, New Jersey. The GOR Skimmer was tow tested in harbor chops, regular waves, and calm water at tow speeds through 2 knots to determine the effectiveness of modifications made to the device since it was last tested. The performance was consistently lower after the modifications in all conditions. The Hydrovac Veegarm was the most exhaustively tested skimmer in this program. The skimmer proved to be a high throughput efficiency, low recovery efficiency, weir-based skimmer. This device had particular difficulties with short wavelength waves at all tow speeds. This device demonstrated high structural integrity throughout the tests.

The Kebab 600, Wylie Skimmer, and Skim-Pak Cluster were tested under a program developed especially for small businesses. The Kebab 600 was a stationary skimmer that demonstrated high recovery efficiency, and (by design) low recovery rates. The Wylie skimmer was constructed from spare parts with minimal capital investment. This device failed to collect oil in all but the mildest test environments. The Skim-Pak Cluster was tested as an extrapolation of previous testing. This testing confirmed that previous test results could be extended to multiple use of the skimming head.

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OHMSETT TEST SERIES 77: GLOBAL OIL RECOVERY SKIMMER, VEEGARM SKIMMING ARM, KEBAB 600, WYLIE SKIMMER, AND THE SKIM-PAK CLUSTER

by

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources; to preserve and treat public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communiations link between the research and the user community.

This report describes a series of test programs run at the USEPA's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT). These programs were sponsored by the OHMSETT Interagency Technical Committee (OITC). The OITC is comprised of the U.S. Navy, U.S. Coast Guard, U.S. Geological Survey, and Environmental Canada in addition to the U.S. Environmental Protection Agency. This consortium of agencies, each having an interest in oil spill removal equipment, annually sponsors testing at OHMSETT. This report describes the testing of five oil skimmers during 1980. The report is presented by Mason & Hanger-Silas Mason Co., Inc. as fulfillment of Contract No. 68-03-2642, Job Order 77. Further information may be obtained through the Solid & Hazardous Waste Research Division, Oil and Hazardous Materials Spills Branch, Edison, New Jersey.

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This report was submitted in fulfillment of Contract No. 68-03-3056 by Mason and Hanger-Silas Mason Co., Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period January, 1980 to June 1981, and work was completed as of August 1983.

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METRIC TO ENGLISH

To convert from	to	Multiply by
Celsius	degree Fahrenheit	$t_C = (t_F - 32)/1.8$
joule	erg	1.000 E+07
joule	foot-pound-force	7.374 E-01
kilogram	pound-mass (lbm avoir)	2.205 E+00
metre	foot	3.281 E+00
$metre_2$	$inch_2$	3.937 E+01
$metre^2$	$foot^2$	1.076 E+01
$metre^3$	$inch^2$	1.549 E+03
$metre^3$	gallon (U.S. liquid)	2.642 E+02
metre	litre	1.000 E+03
metre/second	foot/minute	1.969 E+02
metre/second	knot	1.944 E+00
$metre^2$/second	centistoke	1.000 E+06
$metre^3$/second	$foot^3$/minute	2.119 E+03
$metre^3$/second	gallon (U.S. liquid)/minute	1.587 E+04
newton	pound-force (lbf avoir)	2.248 E-01
watt	horsepower (550 ft lbf/s)	1.341 E-03

ENGLISH TO METRIC

centistoke	$metre^2$/second	1.000 E-06
degree Fahrenheit	Celsius	$t_C = (t_F - 32)/1.8$
erg	joule	1.000 E-07
$foot_2$	$metre_2$	3.048 E-01
$foot^2$	$metre^2$	9.290 E-02
foot/minute	metre/second	5.080 E-03
$foot^3$/minute	$metre^3$/second	4.719 E-04
foot-pound-force	joule	1.356 E+00
gallon (U.S. liquid)	$metre^3$	3.785 E-03
gallon (U.S. liquid)/minute	$metre^3$/second	6.309 E-05
horsepower (550 ft lbf/s)	watt	7.457 E+02
$inch_2$	$metre_2$	2.540 E-02
$inch^2$	$metre^2$	6.452 E-04
knot (international)	metre/second	5.144 E-01
litre	$metre^3$	1.000 E-03
pound force (lbf avoir)	newton	4.448 E+00
pound-mass (lbm avoir)	kilogram	4.535 E-01
$pound/foot^2$	pascal	4.788 E+01

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The author wishes to acknowledge the U.S. Navy, the U.S. Coast Guard, the U.S. Geological Survey, and the U.S. Environmental Protection Agency for providing support, guidance, and funding for the testing. He further wishes to acknowledge the technical assistance provided by the owner of each device tested.

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SECTION 1

INTRODUCTION

OHMSETT test series 77 was funded by the OHMSETT Interagency Technical Committee (OITC). OITC members are committed to maintaining an active knowledge of the current state-of-the-art in oil spill response equipment. In order to make effective use of funds, to ensure the widest possible distribution of obtained information, and to avoid costly repetition of testing, these agencies have pooled their resources and experience for testing three advancing and two stationary skimmers during the 1980 OHMSETT test season. The three advancing skimmers chosen for testing were the Global Oil Recovery (GOR) skimmer, the Veegarm Sweeping Arm, and the Wylie skimmer. The stationary skimmers were the Kebab 600, a rotating disc device, and a floating weir skimmer, the Skim-Pak Cluster.

The GOR skimmer is a modification of the DiPerna Sweeper, which had been tested at OHMSETT previously (see Breslin,[1] Performance Testing of the DiPerna Sweeper). The external head had been removed and a floating weir substituted. Three rows of angle iron had been welded across the front of the weir to dissipate waves prior to contact with the weir. The one-week test program was intended to give a comparison of pre- and post-modification performance to evaluate the modifications to the skimmer.

The Veegarm is a rigid boom skimmer in commercial use around the world. The skimmer is manufactured and marketed by Hydrovac Systems BV, Holland. The skimming arm was the only part of the skimming system tested.

The Wylie skimmer is a prototype skimmer designed for use with a boom rigged in a catenary configuration. An extended free-floating head is intended to remove thickened oil from behind the apex of the boom. The Wylie skimmer is built around an open-ended vertical tank for oil-water separation.

The Kebab 600 is a stationary disc skimmer. A set of four rotating oleophilic discs collect oil that has already been contained. The device is intended for use when low-water-content oil recovery is critical, in applications where the spill has been brought under control.

[1]Breslin, M. K. 1981. Performance Testing of the DiPerna Sweeper. NTIS No. PB82-109-174.

The Skim-Pak Cluster is an extension of a concept previously tested at OHMSETT. (See Lichte and Breslin,[2] Performance Testing of Selected Oil Skimmers Developed by Small Businesses). The Cluster is an extension of the Skim-Pak skimming system concept. Rather than a single skimming head-pump combination, six heads are coupled to a common manifold to scale up the oil recovery rate of the unit without significant reduction in recovery efficiency.

[2]Lichte, H.W., and Breslin, M.K. Performance Testing of Selected Oil Skimmers Developed by Small Businesses. (in press).

SECTION 2

GLOBAL OIL RECOVERY SKIMMER

INTRODUCTION

The Global Oil Recovery Skimmer (GORS) is a modified version of the DiPerna skimmer tested at OHMSETT in 1979. The GORS was tested to determine the effectiveness of the modifications to the DiPerna skimmer. The majority of the modifications involved the oil collecting mouth of the device. The vacuum head of the DiPerna Sweeper was removed and a floating weir installed as a replacement. Three staggered rows of 51-mm angle iron were welded vertically across the bow of the skimmer to dissipate the waves before reaching the weir.

The GORS uses a 6.3 m^3 holding chamber maintained at slightly less than atmospheric pressure to draw oil over the weir. The chamber is baffled and serves essentially as a gravity oil/water separator. The heavier, water-rich layer is pumped from the bottom of the chamber to reduce the internal pressure and draw additional fluid over the weir. The floating, oil-rich layer is pumped from the top of the holding chamber to a more permanent storage area, or the container is used as temporary storage until such time as the skimmer can be offloaded. The GORS is shown before modification in Figure 1, and the modifications are shown in a line drawing in Figure 2.

The test results are treated in two distinct fashions. First, they are presented as if the GORS were being tested for the first time, as a prototype skimmer. Second, the results are listed as a comparison of the initial test results with a percent improvement for evaluation of the modifications.

CONCLUSIONS

The results of the 43 pre-modification and 38 post-modification tests indicate that the principle involved in the system is sound. The results also indicate that the modifications were detrimental to the overall performance of the skimmer. In virtually all cases where the test conditions were repeated, the performance deteriorated. This was especially true of the wave-dissipating angle-irons which tended to concentrate the wave energy and entrain oil rather than dissipate the wave energy.

The mechanical problems that plagued the test series were generally the result of poor engineering and/or maintenance:

1. The free-floating weir did not have the center of buoyancy and center of gravity in the same vertical plane, which caused the weir to twist and jam when rising or falling. The tests were run with a man constantly in position to free the weir. It is, however, unrealistic to have a man on station 24 hours per day for this purpose for spills in the real world.

Figure 1. The Global Oil Recovery skimmer prior to modification under test at OHMSETT in 1978. Notice the skimming head connected to oil control booms advancing ahead of the skimmer. The poor performance of this head, especially in waves as shown, prompted the modification which turned the DiPerna Sweeper into the GORS.

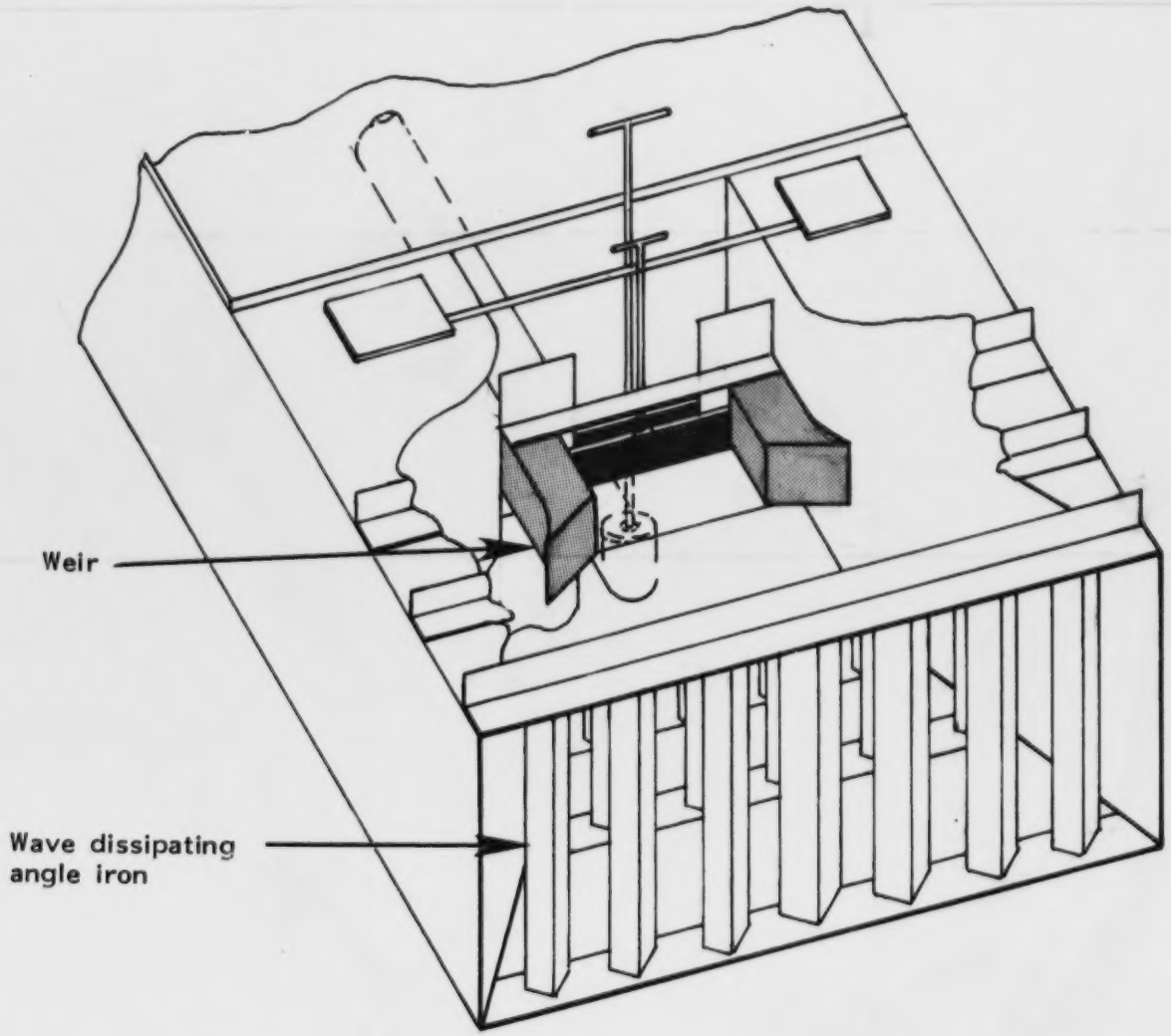


Figure 2. Cut-away view of the bow of the COR skimmer.

2. The GORS came equippped with six onboard pumps. The two single-diaphragm pumps that were intended to offload the oil-rich phase could not overcome a 4-m head. This head could easily be encountered when offloading into barges at sea, so the pump system is simply under-designed.

3. Two centrifugal pumps intended to offload the water-rich phase had been exposed to the elements too long a time without routine scheduled maintenance. Much valuable test time was lost in coaxing these to work. Eventually, an OHMSETT positive-displacement pump was used to pump through one of the onboard centrifugals.

4. The theoretical waterline should have been calculated and the play of the weir been designed accordingly.

The above-mentioned problems are minor and easily remedied with a minimal investment of time, money, and effort. They are not detrimental to the concept of at-sea separation of collected oil and water and should be considered to be flaws in concept implementation rather than flaws of the concept itself. The limited accessibility of storage barges and tugs at a spill makes the concept attractive.

RECOMMENDATIONS

The GORS concept should not be abandoned because of modifications that did not pan out. The wave-dissipating angle iron should be removed and the simpler weir problems corrected. The theoretical relationships developed by extensive research on rectangular gravity separators should be balanced with marine design criteria for buoyancy and stability for optimal on-site separation of the oil and water phases.

A way to remove the operator from onboard the skimmer should be found. The cost of labor and the inconvenience of being stranded are both detrimental to this type of operation. Hydraulics and/or process control valves commonly used in petrochemical plants could be used to eliminate the manning requirement.

DESCRIPTION OF TESTING

The GOR skimmer was towed at speeds through two knots in various wave conditions. The skimmer testing was concentrated on calm water and a 0.30-m harbor chop (HC) for comparison with previous testing. All tests were run using Circo X-heavy oil with a constant incident slick thickness of 2 mm.

Device Description

The GOR skimmer is a rectangular barge with an overall length of 4.9 m, a beam of 2.4 m, and a 3.5 m draft. It is constructed of welded steel plates . Three rows of vertical angle iron have been welded in front of a free-floating weir at the bow of the device. A standard 203-mm (8-in) pipe is used to drain a free-floating weir mounted behind the angle iron. The collected fluid is drawn into the internal holding chamber where the collected oil and water are gravity separated into an oil-rich layer and a water-rich layer. The water layer is continuously pumped overboard to draw

additional fluid from the weir. The deck of the skimmer has six pumps attached for selective offloading of either or both of the separated layers. The GOR skimmer is shown in three test conditions in Figures 3, 4, and 5.

Test Description

The GOR skimmer was towed from North to South by the main bridge into waves. Circo X heavy oil was distributed over a 3-m width at a metered rate to produce a 2-mm slick thickness. The properties of the test oil are listed in Table 1. Distribution of oil began only after the flow of water over the weir was visually equal to the discharge rate from the pumps. Water jets were used to control the slick and guide it into the mouth of the skimmer. The water-rich layer was discharged directly overboard into the test tank. The oil-rich layer was pumped to the auxiliary bridge collection tanks for measurement and sampling. Figure 6 shows the test layout. The tests were conducted as follows:

1. Announce test number, speed, and conditions.
2. Start wave generator, if appropriate.
3. Set oil distribution rate in the recirculation mode.
4. Bring device to designated speed.
5. Balance pump discharge with weir overflow.
6. Begin oil distribution and observe skimmer behavior during steady-state test conditions.
7. Terminate oil distribution and stop tow bridge.
8. Offload collected oil to auxiliary bridge collection tanks.
9. Record collected volume.
10. Strip excess water, record remaining volume.
11. Sample remaining oil and water mixture.
12. Send sample to laboratory for oil/water percentages using the procedure described in ASTM D1796-75.
13. Lower skimming barrier for tow back.
14. Prepare for next test.

A few of the tests varied slightly from this procedure in that, in most wave tests, all of the pumps had to operate to balance the discharge with the weir overflow.

Figure 3. GOR skimmer under test in calm water. Notice the oil overflowing from the mouth of the skimmer. This oil entered the mouth of the skimmer, but because of inadequate weir alignment and pumping it was not collected by the skimmer.

Figure 4. GOR skimmer under test in 0.4-m high, 24-m long regular wave. Notice the higher oil loss from the mouth of the skimmer. Although this type of loss was also evident in calm water (see figure 3), it was much more pronounced in waves. The loss is accentuated by the poor weir response in wave.

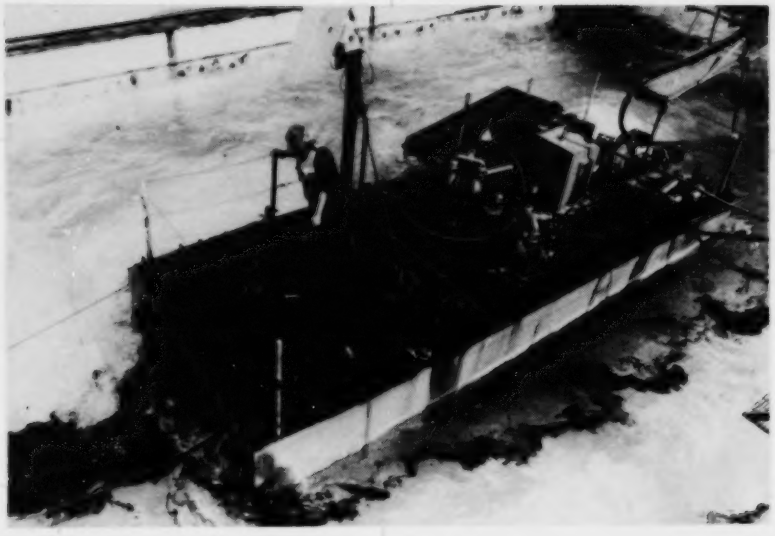


Figure 5. Two views of the GOR skimmer in a Harbor Chop. The top view is taken in a 0.3-m Harbor Chop and the bottom in a 0.2-m Harbor Chop.

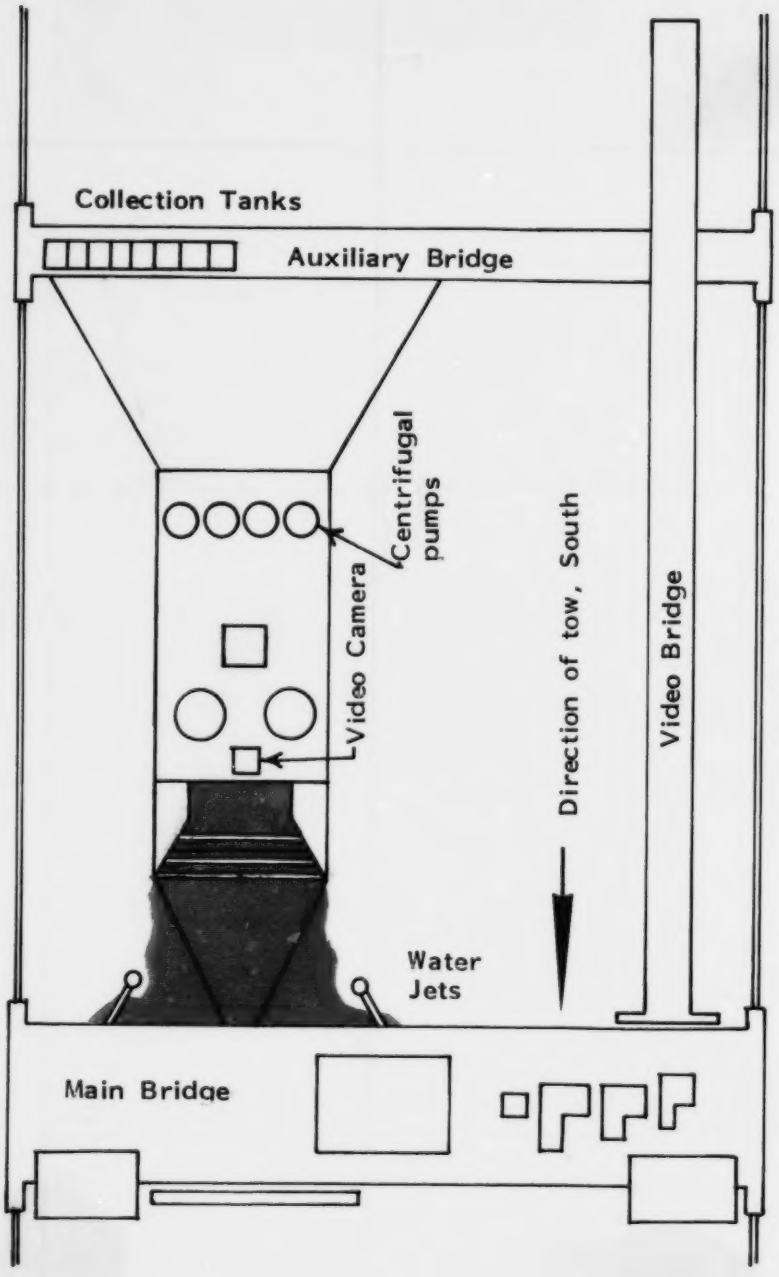


Figure 6. Test set-up for GOR skimmer.

TABLE 1. SUMMARY OF PHYSICAL PROPERTIES OF TEST OIL

Test Day	1	2	3	4
Specific gravity	0.933	0.937	0.938	0.925
Viscosity (cSt) @ 25°C	716.0	810.0	800.6	691.9
@ 72°C	28.5	33.2	34.9	28.0
Surface tension (dynes/cm)	33.9	33.6	34.4	33.6
Interfacial tension (dynes/cm)	19.6	26.6	27.1	22.6
Bottom solids & water (%)	0.1	0.1	0.0	0.0

The viscosity of test oil was obtained at about 25°C using a Brookfield Model LVT viscometer and at 75°C using a Fisher/Tag Saybolt viscometer. The viscosity is converted to centistokes (cSt) using ASTM STP 43C. Surface tension and interfacial tension with test tank water was found using a Fisher Scientific Model Surface Tensiomat at room temperature. Specific gravities were obtained using a hydrometer. The percent water and bottom solids was determined using ASTM D1796-75.

The GOR skimmer was tested for four days. Data were collected from 38 individual tests. Not all planned tests were run. Several sections of the original test plan were abandoned after the start of testing, and new sections were substituted based on the preliminary results. Certain other portions of the test plan were not accomplished due to the large amount of time spent on mechanical problems that developed. The tests that were completed fall into individual sections based on the goals of that section.

Offloading

Four individual methods of offloading oil from the skimmer were attempted. Two of these were unsuccessful. The positive displacement pumps intended for this purpose could not achieve the head necessary to reach the recovery containers (4 m). In the second technique attempted, a fire hose was fitted to the compartment so that salt water could be pumped in to pressurize the compartment to 680 kPa. This method was discontinued when internal banging indicated the possibility of weld failure.

Two successful techniques were employed. First, air-operated double-acting diaphragm pumps were placed aboard and used to offload the oil-rich phase through camlocks couplings attached to a deck hatch located amidship. The second (and final) offloading procedure involved partially disassembling the on-deck piping and installing positive-displacement pumps that could supply the required head.

Ballasting

Balancing the weir overflow with the pumping discharge was difficult in calm water and almost impossible in wave conditions. If the pump discharge rate was too high during the test, the GORS would rise in the water. The floating weir would then rise out of the water on the stops, blocking all oil collection. Maintaining proper flotation was a recurring problem when the GORS was tested in a 0.30-m HC. In an attempt to solve this nuisance, water was pumped into both longitudinal flotation sections to raise the water line an arbitrary distance of 51 mm. The skimmer simply would not collect fluid if the waterline was below the travel of the weir. In tank testing, the ballasting was a small problem. In actual use, however, this would be a serious shortcoming.

Waves

Four different waves were chosen as independent environmental variables. Two of the waves were regular, non-breaking waves. A wave 0.40-m high and 24.2-m long was used for comparison with the earlier testing that led to the modfications. A second regular wave 0.32-m high and 6.2-m long was used because this wavelength is very close to the length of the GORS. The third and fourth waves were 0.20-m and 0.30-m harbor chops. The 0.30-m HC was chosen for the comparison with earlier test data, again for a quantitative measure of the effectiveness of the modifications. The smaller HC was chosen to demonstrate the dependence of performance on wave height.

TEST RESULTS

The GORS testing yielded values for throughput efficiency (TE), recovery efficiency (RE) and oil recovery rate (ORR). Whenever the tests were run for comparison of these skimmer rating criteria based on before- and after-modification performance, the percent improvement and absolute improvement are given.

The RE is not a clear-cut rating criterion in this testing. The device is essentially a floating, gravity-type, oil/water separator. The effluent oil quality essentially becomes the RE of the skimmer. In real world spills, the skimmer would be operated with much longer residence times than those encountered during testing, probably leading to higher RE values. Because of this vagueness, RE was not reported in the previous testing.

The ORR is the rate of oil removal from the environment. The ORR is not dependent on the rate that oil is accumulated in the auxiliary bridge because the transfer rate was arbitrary and not necessarily equal to the oil collection rate. Physically, the ORR for these tests can be considered to be the rate at which oil passes over the weir into the GOR skimmer.

The percentage improvement in skimmer performance has been arbitrarily defined to be the ratio of the difference in skimmer performance to the past performance in the same test conditions. In mathematical terms, the percent improvement in the throughput efficiency (PITE) would be defined as (TE_{AM} minus TE_{BM}) divided by (TE_{BM}) multiplied by 100, where the subscript AM refers to the TE after modifications and BM refers to the TE before modifications. Similarly the Percent Improvement in Oil Recovery Rate (PIORR) would be defined as (ORR_{AM} minus ORR_{BM}) divided by (ORR_{BM}) multiplied by 100. The absolute difference would simply be the algebraic difference in the performance after modification and before modification. The absolute improvement in throughput efficiency (AITE) is defined (TE_{AM} minus TE_{BM}), the difference in throughput efficiencies before and after modifications. Likewise, the absolute improvement in oil recovery rate (AIORR) is defined (ORR_{AM} minus ORR_{BM}). The recovery efficiency comparison is not possible as this data is not given in the first test series.

A negative value in either the absolute or percentage differences would indicate a net decrease in skimmer performance. The tests conducted before modification used a slick 12 mm thick as measured at the weir, but was of a similar thickness at the boom entrance. Since no significant loss is reported from boom failure, it is assumed that there was no such loss and the comparison of oil recovery rates is valid.

Offloading Technique (calm water tests)

The difference in the means of offloading the collected oil appears to be of little consequence. Offloading oil through the hatch generally provided slightly better TE values through one knot and slightly lower values at speeds of 1.5 knot and above. The maximum TE occurred at 0.75 knot when offloading through the intended pump port. TE is graphed against tow speed in Figure 7. The RE was higher when offloading through the hatch at speeds above one knot but lower at speeds of one knot or less. It is believed that the decreasing RE is more the result of greater oil-water emulsification as both fluids pass through the wave dissipators at the higher speeds than it is the result of the separation concept. The reversal of the method giving better RE indicates that this is indeed a criterion based on factors other than the offload port location; i.e., one port is no better than the other. A maximum RE of 75% was achieved at 0.5 knot. The RE is graphed against tow speed in Figure 8. The ORR reacts in the same fashion as the RE and TE with the optimal offload port changing at 1 knot. The maximum ORR obtained was nearly 15 m^3/hr at 1.5 knot, as shown in Figure 9. The choice of offload port is apparently of only minor consequence when these two locations are chosen.

A summary of the pre-and post-modification results is given in Table 2. The average value of the two is listed for comparison with the calm water runs of the skimmer before the addition of wave dissipators and the free-floating weir. The change from the calm water results is consistently negative, with the magnitude of decrease in performance increasing with tow speed. The TE is probably decreasing primarily because of the wave dissipators. The slick is driven into the water by the wave dissipators, and the oil dispersion caused by the wave dissipators appears to increase with tow speed. Since the weir would have little effect on skimmer performance in calm water, the majority of the decrease can be attributed to the wave dissipators in these tests.

TABLE 2. CALM WATER TEST RESULTS and COMPARISONS OF PERFORMANCE BEFORE AND AFTER MODIFICATIONS OF THE GOR SKIMMER

Tow speed (kt)	TE (%)	ORR (m^3/hr)	PITE (%)	AITE (%)	PIORR (%)	AIORR (m^3/hr)
0.5	85	5.7	-9	-8	-55	-6.9
1.0	80	11.6	-14	-13	-58	-15.1
1.5	60	12.8	-37	-35	-60	-16.6
2.0	20	5.7	-62	-32	-80	-23.6

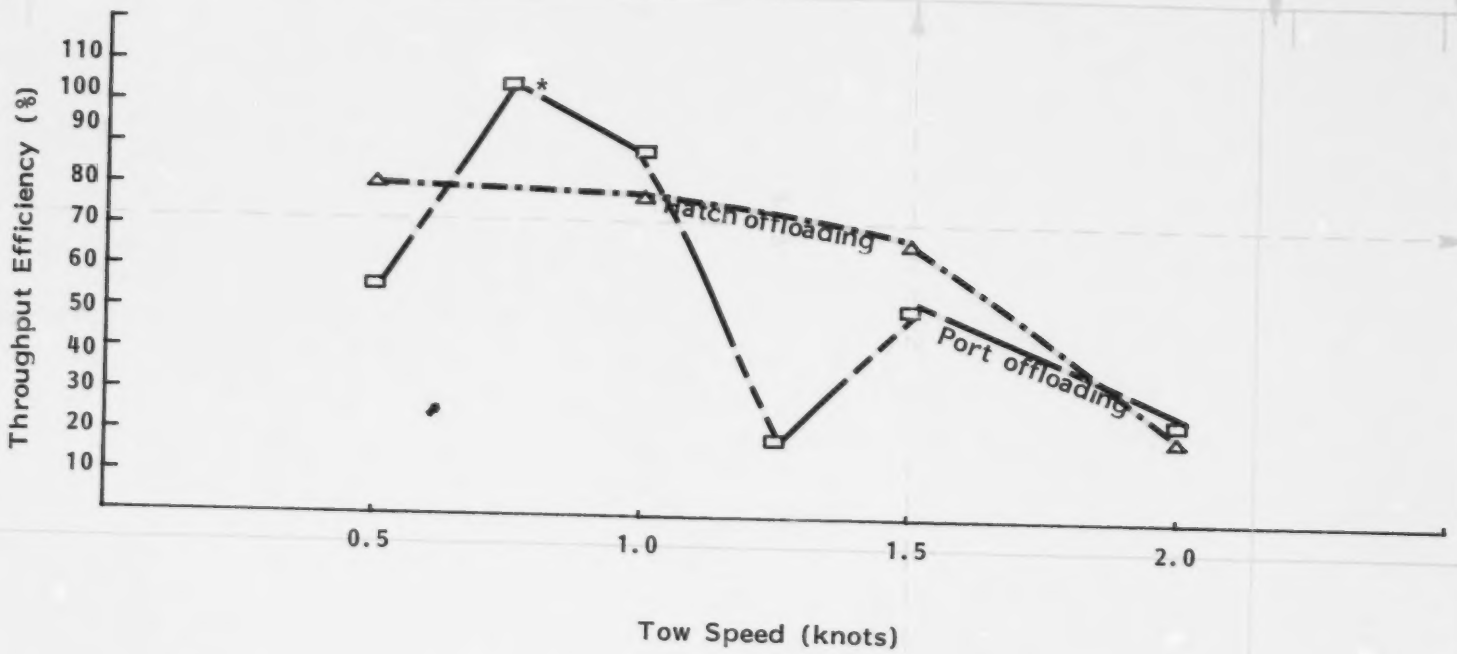


Figure 7. Throughput efficiency of the GOR skimmer in calm water. The computed throughput efficiency is compared for offloading through the hatch (triangles) and offloading through the in-deck port (squares). Notice that the data point marked with the asterisk (*) is above 100%. This is caused by a combination of measurement error and, possibly, measurement of oil collected in a previous test but not transferred for measurement and sampling.

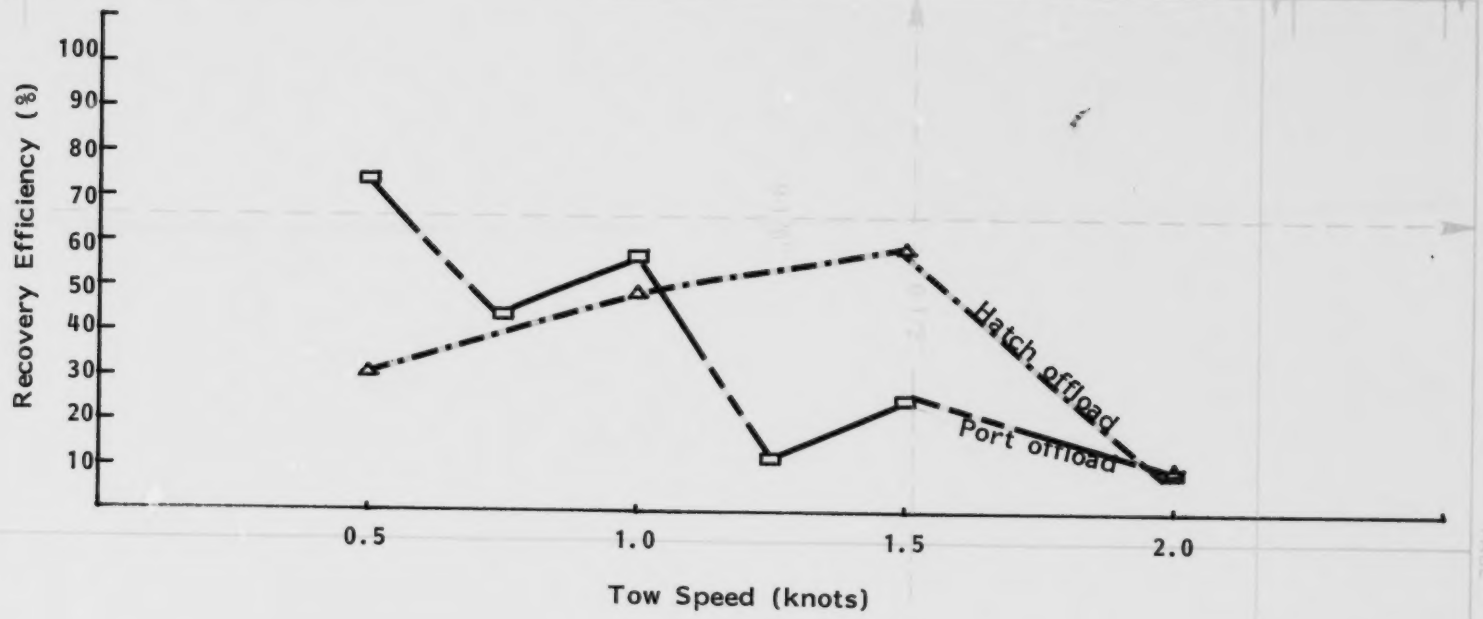


Figure 8. Recovery Efficiency of the GOR skimmer in calm water. The graph compares the difference between offloading through the hatch (triangles) and through the in-deck port (squares).

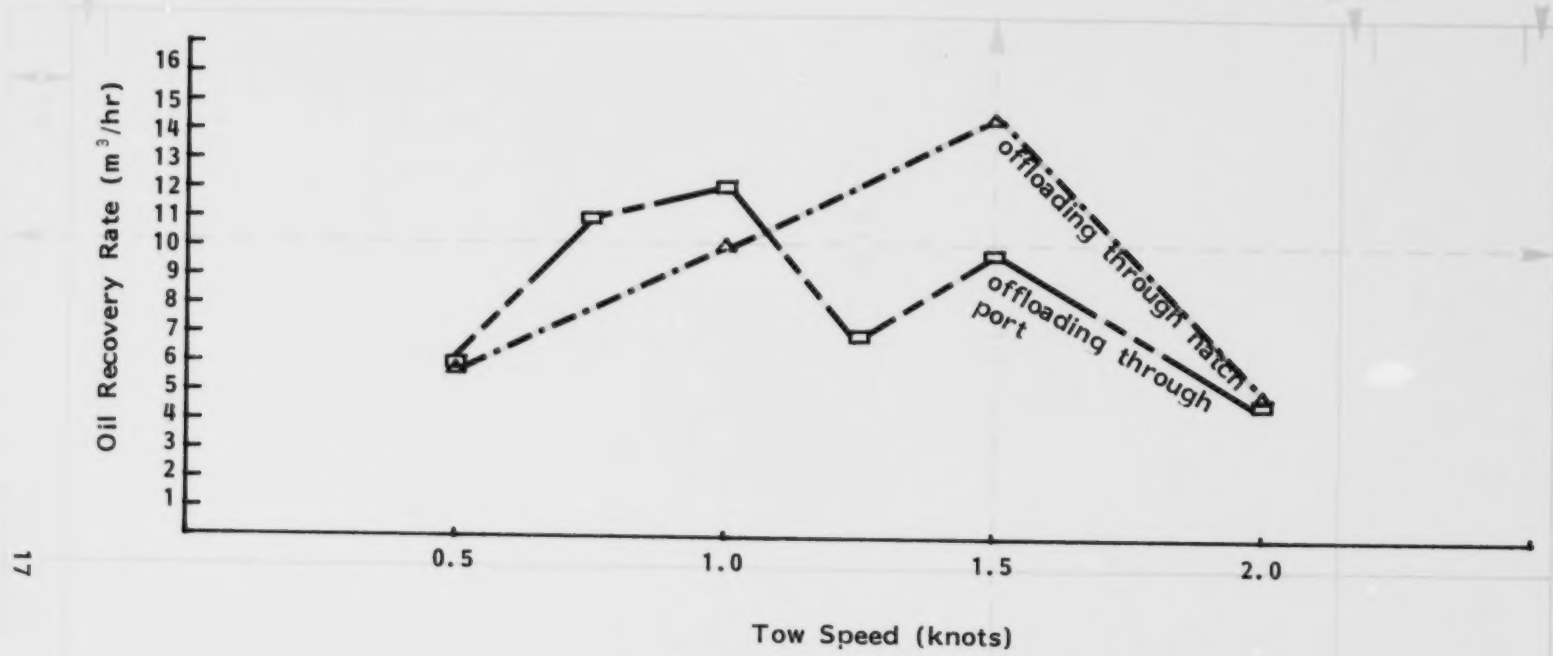


Figure 9. Oil Recovery Rate of the GOR skimmer in calm water. The graph compares the two successful offloading techniques used: offloading through the hatch (triangles) and through the deck port (squares). The Oil Recovery Rate and the rate at which oil overflows the weir are synonymous. It is not the rate of which oil was transferred from the skimmer to the tanks in the auxiliary bridge for measurement and sampling.

Ballasting (0.30 m HC tests)

The great difficulty in balancing the weir overflow with the water pump discharge and the occasional over-pumping that caused the skimmer to rise the weir to strike the bottom stops and stop collecting the oil slick necessitated the proper ballasting of the GORS. During testing, this difficulty generally caused the test to be aborted and run again. A second series of tests were run in the same harbor chop with water pumped into the port and starboard longitudinal flotation sections to raise the water line 51 mm. Because of the short test period, no attempt was made to optimize this ballasting, and the 51 mm value was chosen as an educated guess. After the ballasting, the weir no longer rested on the bottom stops except when the bow of the skimmer passed through a wave trough.

The difference between ballasted and unballasted results is probably smaller than one would expect at an actual spill. The GORS generally did better when ballasted with the exception of those tests run at 0.5 knot. A maximum TE of 45% was obtained with the skimmer ballasted at 1.5 knot as shown in Figure 10. The 0.3-m HC tests gave a maximum RE of 21% at 1.5 knot. The remaining tests gave RE values of 10% or less. The RE is graphed against tow speed in Figure 11. This appeared to be caused in part by the high degree of emulsification that the wave dissipators caused as the wave passed through them. Gravity-type separators have long been known for their inability to separate oil/water or water/oil emulsions and to expect the GORS to do so is unreasonable. A possible secondary cause of the low RE may be the highly viscous, non-Newtonian flow characteristics of emulsions. The offloading pump would evacuate a portion of the oil-rich layer at the surface near the pump inlet; and water, being less viscous than the emulsion, would flow into the resulting crater more readily than the oil-rich layer, giving the impression of a lower RE in the auxiliary bridge tanks than was actually contained within the holding compartment. The ORR was generally less than 10 m^3/hr. The only exception was the 1 knot test which gave 15 m^3/hr with the device ballasted port and starboard. The ORR performance results for the 0.30-m HC tests are shown in Figure 12.

The 0.3-m HC was chosen for comparative purposes. The device was tested in this HC prior to modification; therefore, the PITE, AITE, PIORR and AIORR can be calculated evaluating the modifications. These values along with the ORR results for this test series, averaging the ballasted with unballasted, are given in Table 3. The absolute and percent improvement values are negative with the exception of the TE values at 0.5 knot, which showed a very slight improvement. The wave dissipators again contributed largely to this loss in efficiency. The angle irons generated turbulence and tended to drive the oil into the water column as large, entrained globules, thus lowering the TE and ORR.

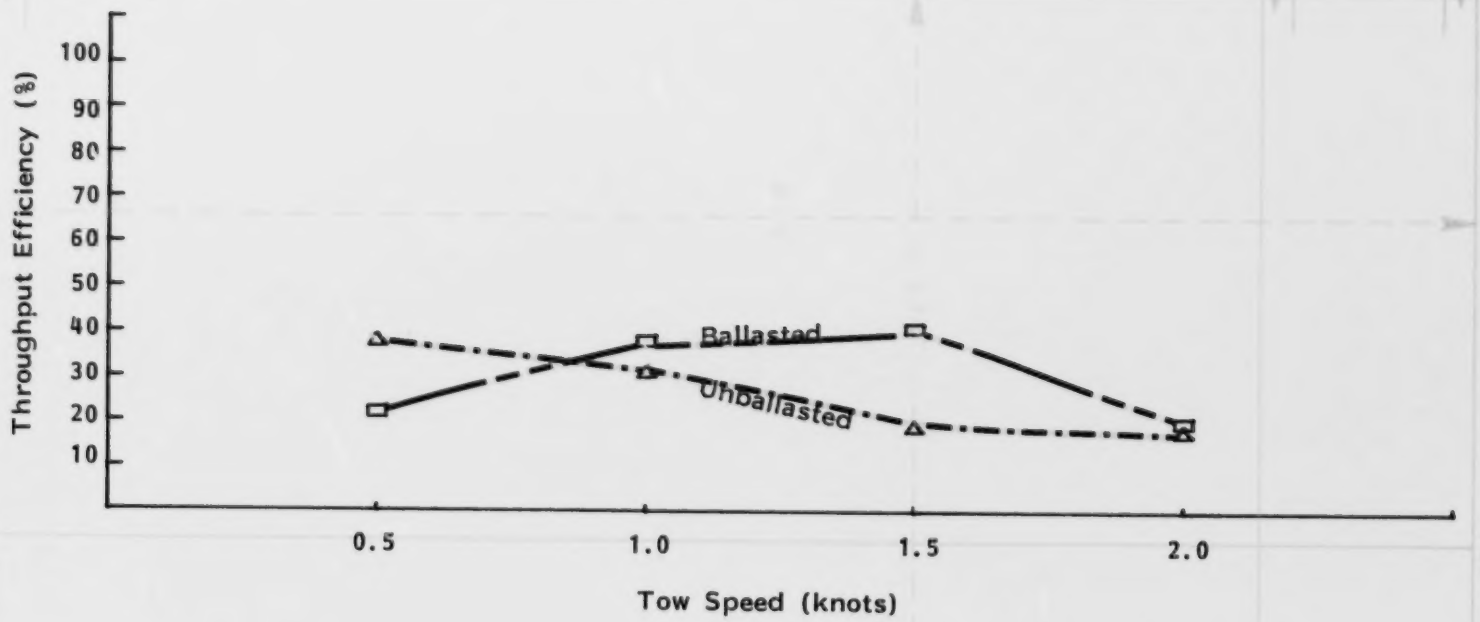


Figure 10. Comparison of the efficiency of the GOR skimmer ballasted (squares) and unballasted (triangles) in a 0.30-m Harbor Chop. The skimmer was ballasted with salt water to raise the waterline, giving the weir a greater level distance. An arbitrary value of 52 mm was selected as the amount to lower the skimmer. There was no attempt to optimize the distance.

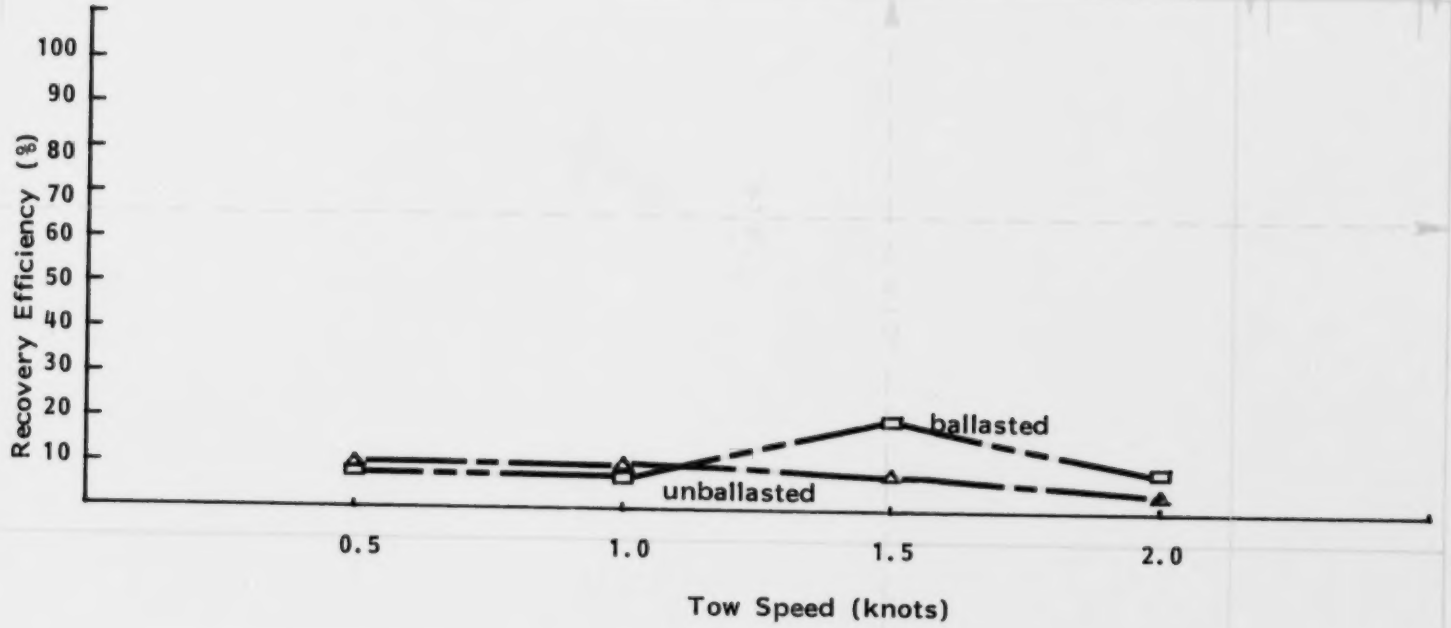


Figure 11. Recovery Efficiency of the GOR skimmer in a 0.3-m Harbor Chop. The effects of ballasting are shown. The recovery efficiency is considerably lower in the 0.3-m Harbor Chop than in calm water (see figure 8 for comparison). The wave dissipating angle iron is believed to have caused much of the lowering in performance.

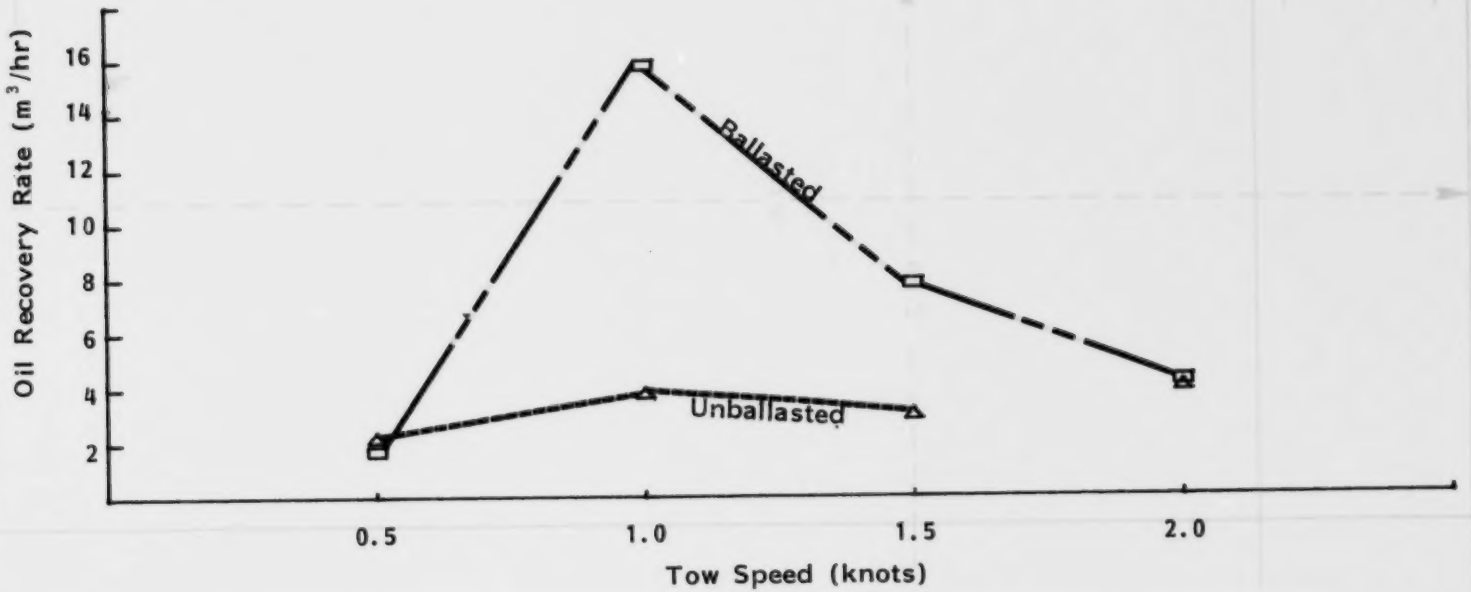


Figure 12. Oil Recovery Rate of the GOR skimmer in a 0.3-m Harbor Chop. The ballasted performance (squares) was superior to the un-ballasted except for the minor difference at 0.5 knots.

TABLE 3. COMPARISON OF THE GORS PERFORMANCE IN 0.3-m HC BEFORE AND AFTER MODIFICATION

Tow speed (kt)	TE (%)	Ave. ORR (m^3/hr)	PITE (%)	AITE (%)	PIORR (%)	AIORR (m^3/hr)
0.5	35	2.0	3	1	-55	-2.4
1.0	37	9.6	-46	-36	-51	-9.8
1.5	30	5.7	-35	-16	-71	-13.6
2.0	21	2.8	-23	-6	-81	-11.6

Harbor Chop Wave Height Comparison

The initial test plan called for a larger wave, 0.63-m, to be used as a HC test for comparison with the 0.30-m HC. The visible results, however, indicated that the 0.3-m HC was probably outside the operating range of the skimmer, so a smaller, 0.2-m HC was substituted.

The performance of the GORS improves in the 0.2-m HC, but the skimmer's performance remains below that measured prior to the modifications in the 0.3-m HC. The TE peaks at 100% at speeds up to 0.75 knot. The TE seems reasonably steady at 60% at speeds above 0.75 knot, as shown in Figure 13. By comparison, the GORS in the 0.30-m HC has a maximum TE of 45%. The RE is again low, peaking at 50% probably because of the emulsification of oil by the wave-dissipating angle irons. At the other tow speeds, the recovery efficiency is generally below 30% as shown in Figure 14. The ORR is higher in the smaller wave, with the exception of the anomaly at 1 knot in 0.3-m HC, as seen in Figure 15. A harbor chop of the smaller size was not used before the modifications; therefore, no comparison of results can be made.

Regular Waves

The GORS was tested in two regular waves. The first, 0.40-m high and 11.6-m long, was part of the test series that was run prior to modifications and allows an evaluation of the modifications based on an absolute and percent improvement basis. The second wave tested had a similar wave height but a shorter wavelength of 6.2 m, approximately the length of the GORS.

The GORS performs well in the longer wavelength, giving a nearly perfect TE of 93% at 0.5 knot and a TE of 85% at 1 knot. The RE is again below 50% primarily due to the emulsification caused by waves passing through the wave dissipators. The RE peaks at 50% with a tow speed of 0.75 knot. The ORR peaks at 11 m^3/hr when the GORS is towed at 1 knot.

Performance in the shorter wave was noticeably poorer, probably because of the increased frequency of crest-trough encounter. A maximum TE of 50% occurs at 2 knots. The oil is forced away from the weir by the bow wave at lower speeds. The RE is again quite low. The maximum obtained was at 1.25 knot and was 30%. The ORR increases with speed up to a maximum of 11 m^3/hr at 1.5 knot. The TE, RE, and ORR are summarized in Figures 16, 17, and 18.

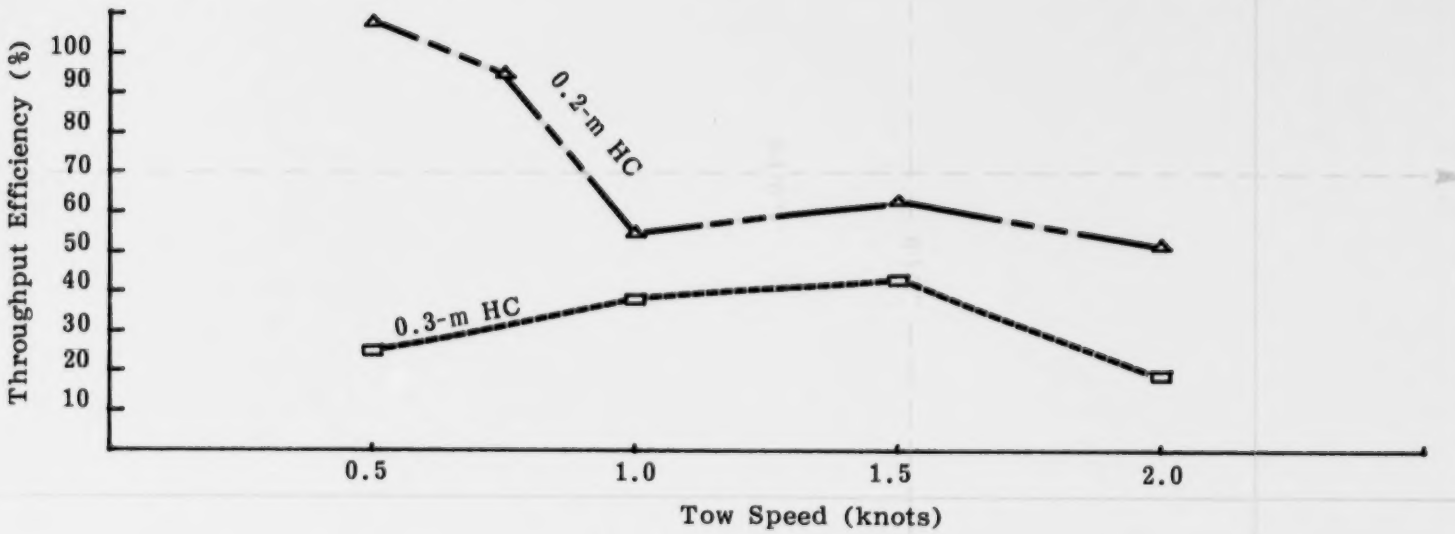


Figure 13. The Throughput Efficiency of the GORS was always higher in the lower Harbor Chop (HC). The Throughput Efficiency at 0.5 knots in the small Harbor Chop was above 100%. This is felt to be caused by a combination of measurement error and the possibility of measuring oil collected in previous tests but not transferred to the measurement sampling tanks.

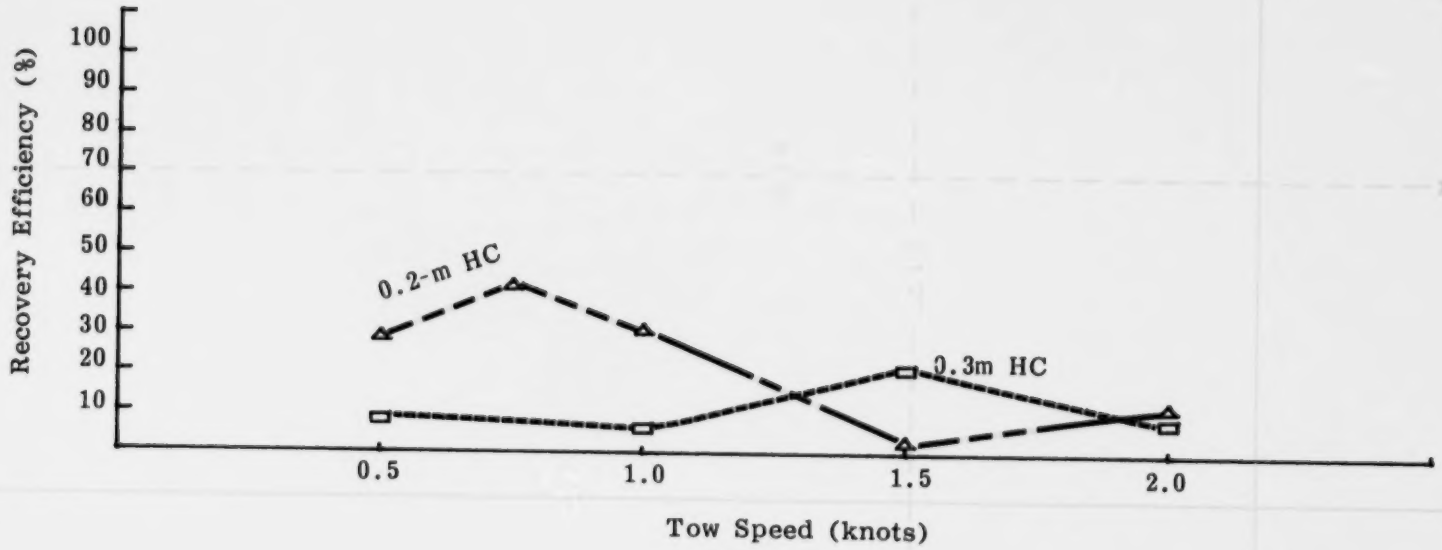


Figure 14. The added wave energy concentrated by the wave dissipating angle iron in the 0.3-m Harbor Chop (HC) emulsified the oil to a greater degree than in 0.2-m Harbor Chop. This resulted in a lower Recovery Efficiency as shown by the squares above.

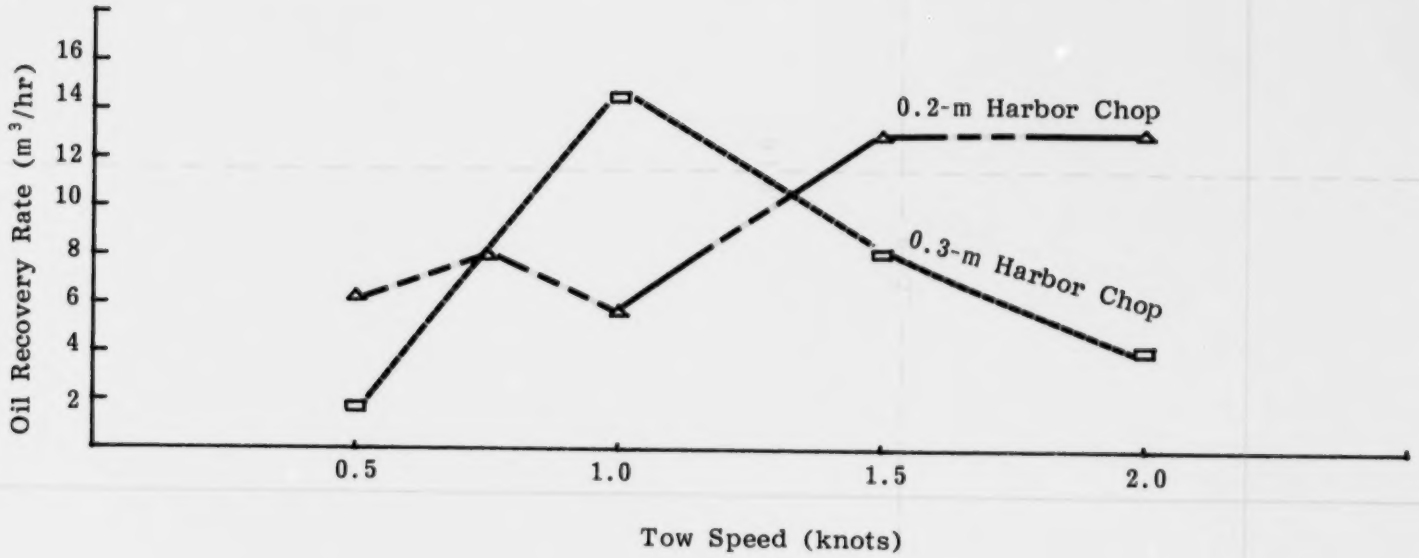


Figure 15. The Oil Recovery Rate of the GORS was higher in the 0.2-m Harbor Chop than in the 0.3-m Harbor Chop at all tow speeds except at 1.0 knot.

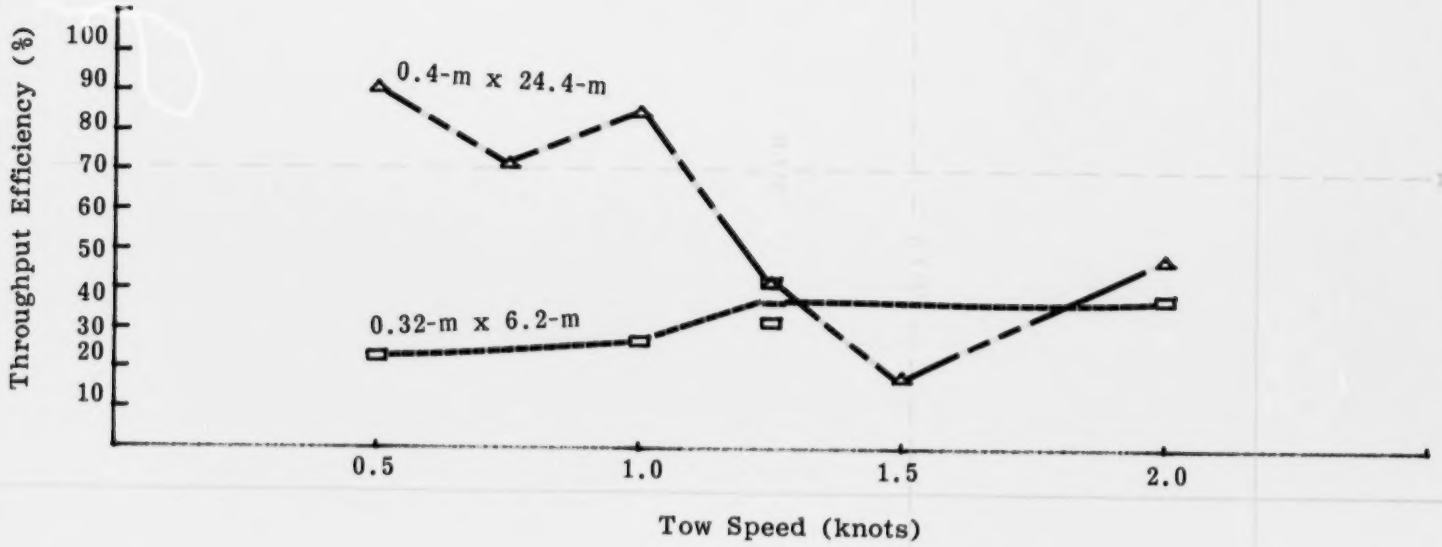


Figure 16. The Throughput Efficiency of the GOR skimmer was generally higher in 0.4-m x 24.4-m regular wave (triangles) than in the 0.32-m x 6.2-m regular wave (squares). When the GOR skimmer was towed into the shorter wave, the frequency of crest-through interactions through the wave dissipators was greater then when towed into the longer wave.

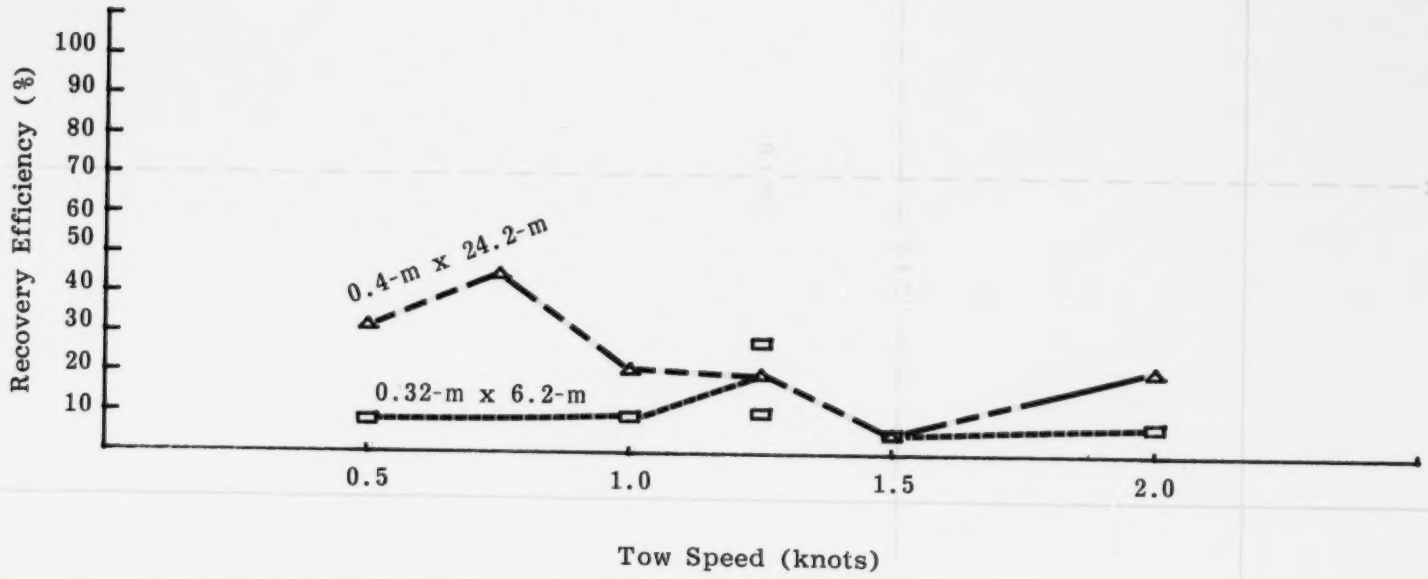


Figure 17. The Recovery Efficiency of the GORS was generally higher in the longer wave.

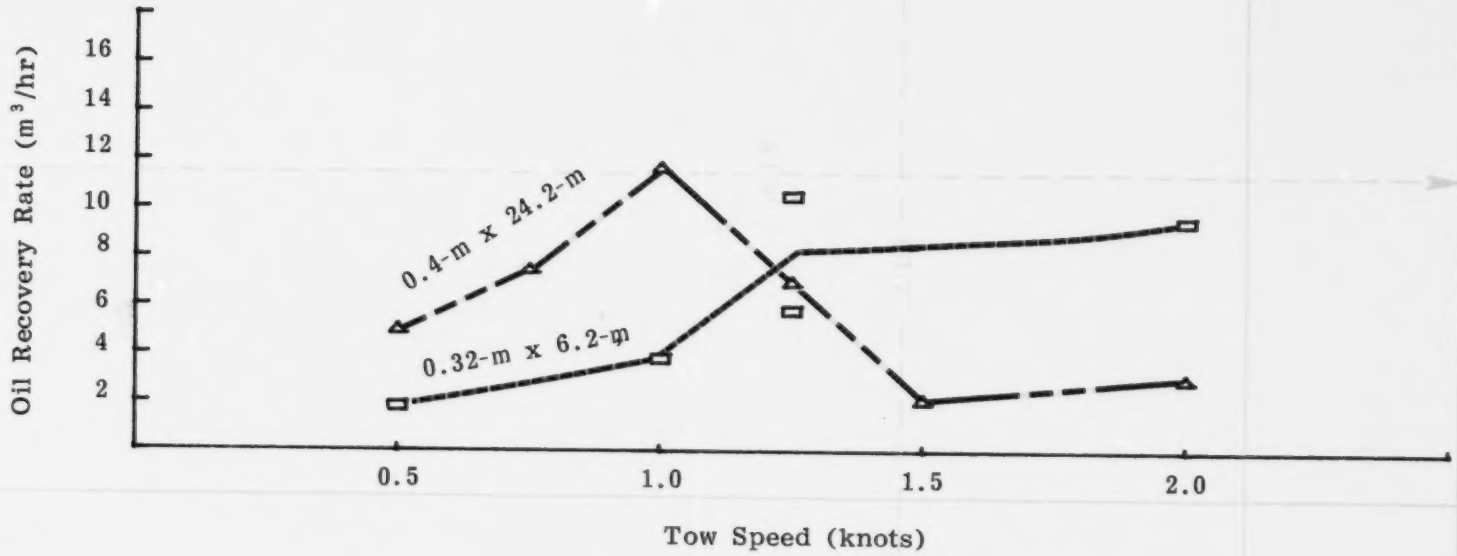


Figure 18. The Oil Recovery Rate of the GOR was higher in the longer wave at tow speeds below 1.5 knots. Above 1.25 knots the trend was reversed.

The 0.40-m x 11.6-m wave was used in the testing of the GORS prior to modifications. The performance in the repeated condition gives a measure of the effectiveness of the modifications. The results of this comparson are given in Table 4. The results for the percent and absolute improvement are generally negative. This, once again, indicates that the modifications to the skimmer are not improvements but are detrimental to the performance of the device.

A summary of all tests and the respective results are given in Table 5 and the results of the pre-modification tests are given in Table 6. The improvement rating criteria are summarized in Figures 19 through 22.

TABLE 4. COMPARISON OF THE GORS SKIMMER PERFORMANCE BEFORE AND AFTER THE MODIFICATION OF THE WEIR, IN A 0.4-m x 11.6-m REGULAR WAVE

Speed (kts)	TE (%)	ORR (m^3/hr)	PITE (%)	AITE (%)	PEORR (%)	AIORR (m^3/hr)
0.5	93	5.0	NA	NA	NA	NA
1.0	85	11.5	273*	+62	+83	+5.2
1.5	17	2.3	-30	-7	-77	-75
2.0	45	4.7	114	+24	-68	-10.0

NA - Data not available for both the before and after modification tests.

*Based on average of two extremely different test results for the before-modification TE and ORR.

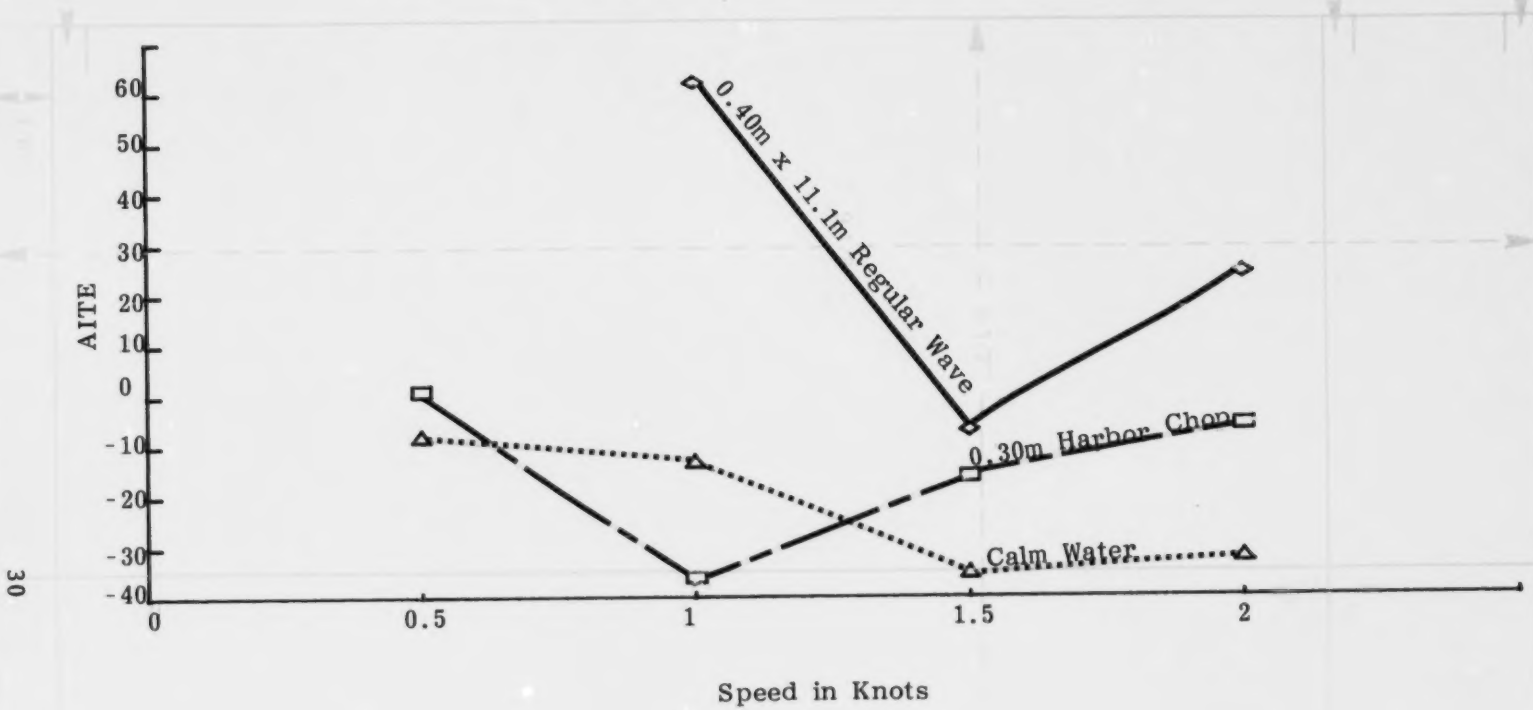


Figure 19. A comparison of the absolute improvement in Throughput Efficiency of the GORS with tow speed in various environmental conditions. Notice, that with the exception of the regular wave tests, the throughput efficiency was always less after the modifications.

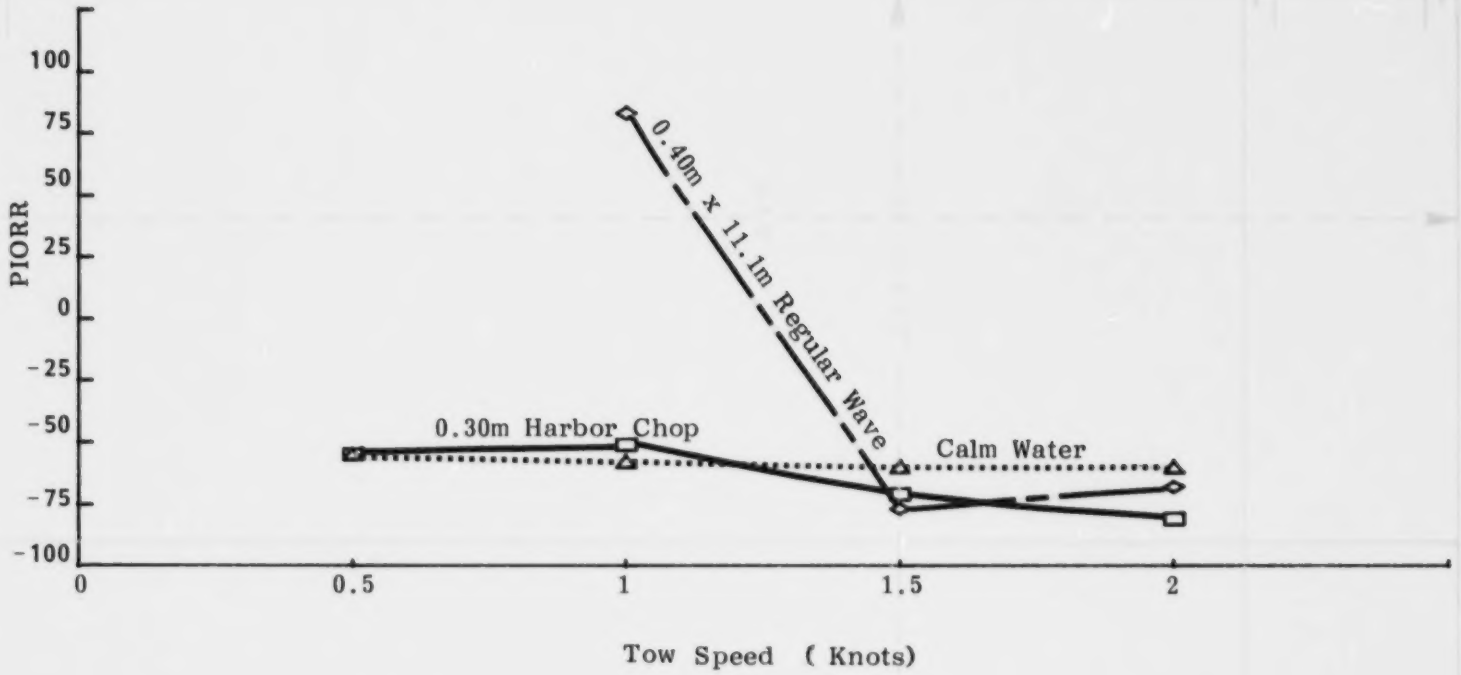


Figure 20. A comparison of the percent improvement in Oil Recovery Rate of the GORS with tow speed in various environmental conditions. Notice the single large positive value obtained in the 0.4-m x 11.1-m regular wave.

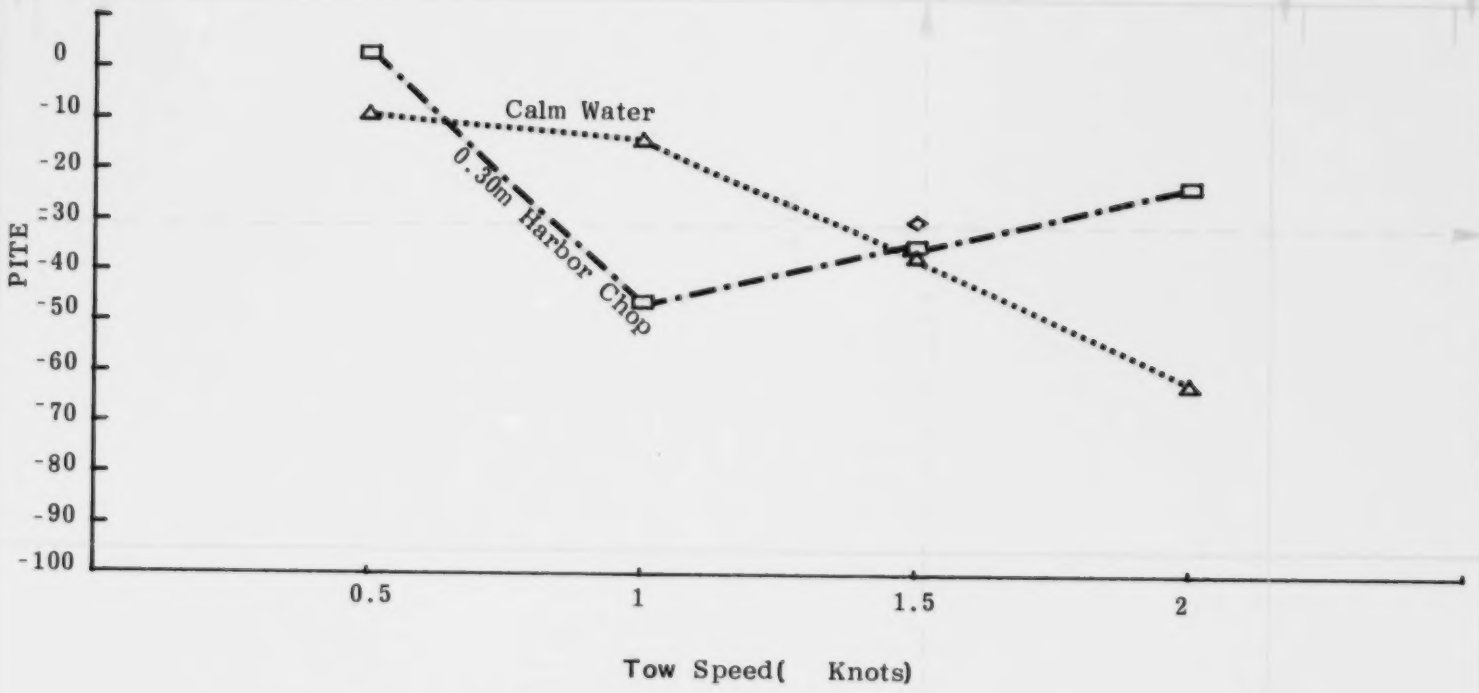


Figure 21. The percent improvement in Throughput Efficiency of the GOR skimmer is shown in various conditions. The second point for the regular wave tests (diamonds) is a large positive value and is not shown to avoid distortion of the remaining points.

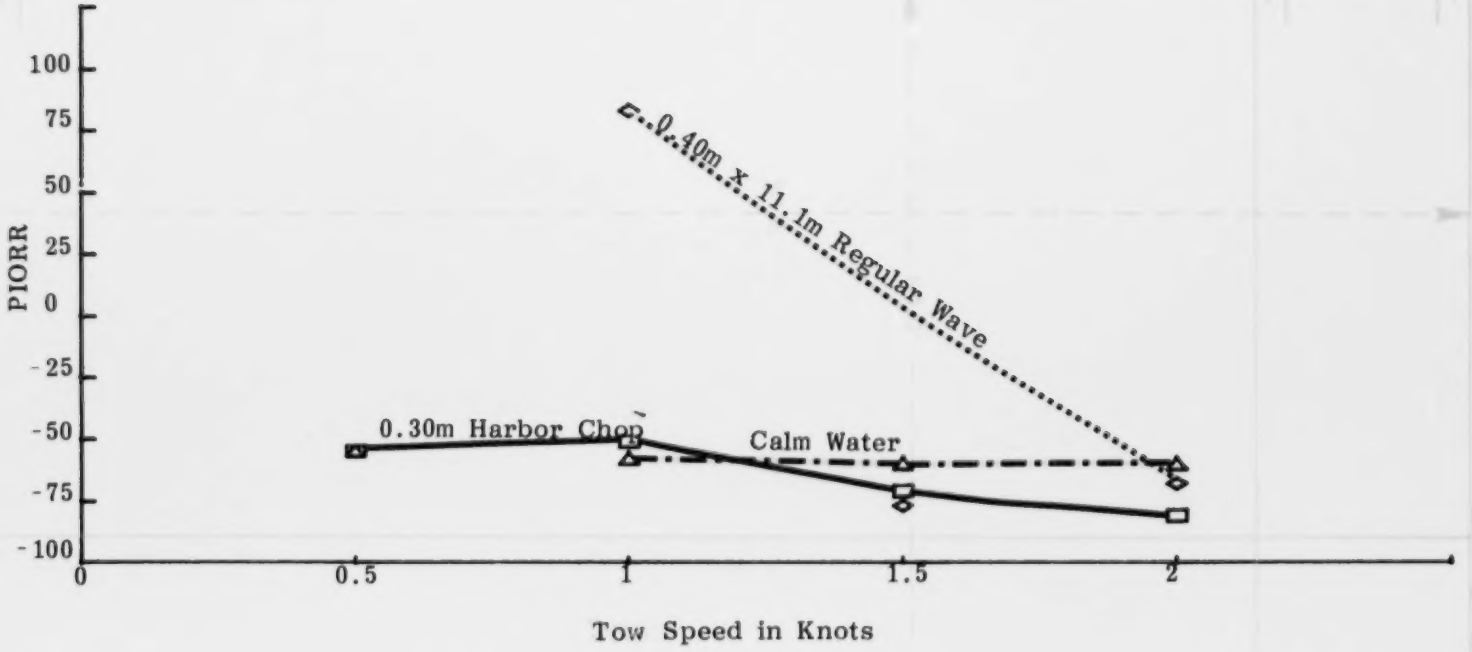


Figure 22. Percent improvement in Oil Recovery Rate for the GORS at speeds through 2 knots. The negative values show the detrimental effects of the modification.

TABLE 5. TEST RESULTS OF THE MODIFIED GORS USING CIRCO X HEAVY OIL

Test no.	Tow speed (kts)	TE (%)	RE (%)	ORR (m^3/hr)
1	0.50	82	33	5.6
2	1.00	77	51	10.6
3	1.50	67	61	15.2
4	2.00	22	11	5.8
1A	0.50	58	75	5.9
2A	1.00	88	59	12.6
3A	1.50	33	81	10.3
4A	2.00	26	9	5.6
5A	0.75	100	47	10.9
6A	1.75	19	17	7.5
7	0.50	93	32	5.0
8	1.00	85	23	11.5
9	1.50	17	5	2.3
10	0.75	73	48	7.5
11	1.25	43	21	7.1
12	2.00	45	23	4.7
13	0.50	38	9	2.5
14	1.00	35	9	4.0
15	1.50	20	6	3.0
18	2.00	18	3	6.0
19	0.50	25	7	1.4
20	1.00	26	9	3.5
21	1.50	38	10	6.2
22	2.00	35	9	9.0
24	1.25	45	24	10.5
37	0.50	32	6	1.4
38	1.00	40	5	15.1
39	1.50	45	21	8.3
40	2.00	23	6	4.0
43	0.50	100	30	6.6
44	1.00	53	30	5.8
45	1.50	64	31	12.8
47	0.75	97	45	5.1

TABLE 6. TEST RESULTS OF THE UNMODIFIED GORS USING HEAVY OIL

Test no.	Tow speed (kts)	Waves (m x m)	Slick thick (mm)	Weir depth (cm)	TE (%)	ORR (m^3/hr)
SD 3	0.5	Calm	11.7	6.35	95.0	12.4
1	0.5	Calm	12.4	6.35	91.3	12.6
2	0.5	Calm	12.4	6.35	93.7	12.9
3	0.75	Calm	13.2	6.35	91.8	20.1
4	0.75	Calm	13.4	6.35	95.0	20.8
5	1.0	Calm	12.9	6.35	94.5	27.2
6	1.0	Calm	12.8	7.62	84.3	24.1
7	1.0	Calm	12.8	6.35	96.2	27.4
8	1.25	Calm	12.9	6.35	97.2	28.1
9	1.25	Calm	10.4	6.35	95.1	27.5
10	0.5	0.3 m HC	11.9	varied	25.7	3.4
12	1.25	Calm	10.1	7.62	93.8	26.5
13	1.5	Calm	12.6	7.62	87.4	36.5
14	2.0	Calm	13.1	7.62	46.9	27.4
15	2.0	Calm	12.8	6.35	55.9	31.8
16	2.5	Calm	12.2	6.35	23.4	15.9
17	0.5	0.3 m HC	12.8	varied	30.7	4.4
18	2.0	Calm	8.7	6.35	34.3	13.3
19	2.0	Calm	9.7	10.16	30.2	13.1
20	2.0	Calm	---	---	---	---
21	2.0	Calm	12.4	11.43	75.3	41.6
22	2.0	Calm	12.1	11.43	69.5	37.3
23	0.5	0.3 m HC	12.0	varied	44.1	5.3
24	0.75	0.3 m HC	11.7	varied	45.2	8.9
25	0.75	0.3 m HC	12.0	varied	80.7	16.2
26	1.0	0.3 m HC	12.0	varied	72.8	19.4
27	1.5	0.3 m HC	12.5	varied	46.4	19.3
28	2.5	Calm	12.2	12.7	33.2	22.5
29	2.0	0.3 m HC	11.8	varied	27.3	14.4
30	0.5	0.4 x 11.6	---	---	---	---
31	1.0	0.4 x 11.6	12.6	varied	38.3	10.5
32	1.5	0.4 x 11.6	12.5	varied	23.5	9.8
33	2.0	0.4 x 11.6	12.5	varied	21.1	11.8
34	2.5	0.4 x 11.6	12.6	varied	21.0	14.7

SECTION 3

THE HYDROVAC VEEGARM

INTRODUCTION

The Veegarm is a rigid-boom oil skimmer produced and marketed by Hydrovac Systems BV of the Netherlands. A rigid arm channels the floating oil slick to a simple overflow weir. The collected fluids are then pumped to a large vessel which serves as an oil-water separator. Only the skimming arm was tested, there were no tests of the arm in conjunction with the support vessel.

The Veegarm was tow tested at speeds through 3 knots in calm water and wave conditions. Two oils of very different viscosity were used as test fluids in varying thicknesses. A total of fifty six tests were performed on the skimmer over ten test days. The tests were designed to demonstrate the effects of tow speed, slick thickness, oil viscosity and wave conditions. A line drawing of the skimming arm is shown in Figure 23.

CONCLUSIONS

The Veegarm is well designed in regard to strength, flotation, and stability. The truss which supports the oil diversion screen is constructed of rectangular steel tubing and will withstand massive forces before permanent deformation occurs. The modular design allows for easy over-the-road transportation and relatively simple air shipment.

The largest wave the Veegarm was tested in was a 0.63-m harbor chop. This was the only wave in which the outboard pontoon left the water surface. Although the Veegarm suffered from occasional splashover, the bottom of the screen never exposed itself for simple oil loss beneath the screen. A headwave of contained oil does appear and remains parallel to the face of the skimmer. The thickened layer of oil presented no real problems along the length of the screen but the head wave was entrained at the weir assembly at higher speeds.

Vortices that form at the ends of the weir draw some oil into the water column. The inboard vortex was of little consequence, because it seldom captured oil. The outboard vortex captured more oil, but the total quantity of oil captured was small in comparison to the total distributed and to losses from other failure mechanisms. Losses occur between the Veegarm and the support vessel hull. The butted union from the tests is shown in Figure 24. The slick lost at this location is generally very thick. When encountering thick slicks in calm water, the percentage of total loss is significant.

The screen of the arm reflects incident waves. The reflected wave strikes the next incident wave and forms a harbor chop. This is especially evident when the waves are short and the arm is unable to respond to changes in the water surface level.

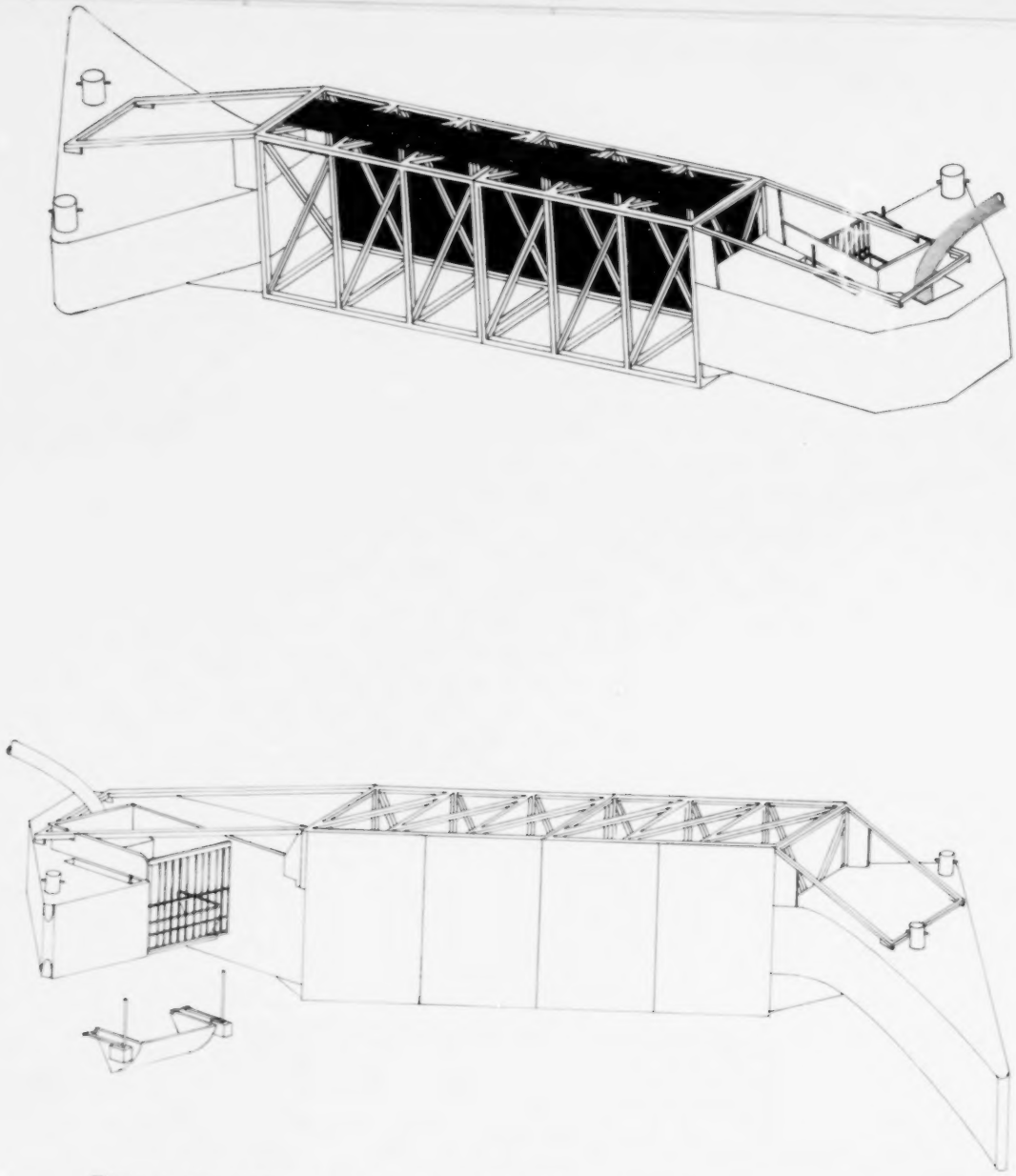


Figure 23. The basic support of the Hydrovac Veegarm is a truss made of rectangular steel tubing. The oil diverison face is made from four plywood sheets. The front view (below) also shows the overflow weir as an offset.

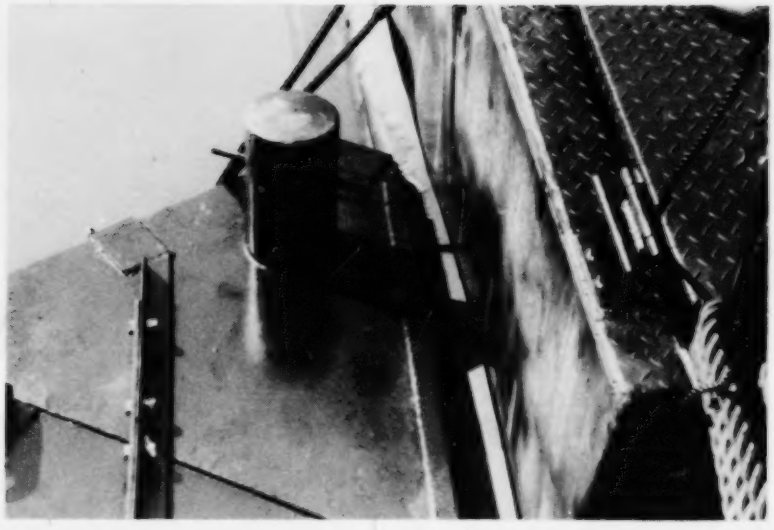


Figure 24. The gap that formed between the Veegarm and the support vessel (right) was a point of significant losses during the testing. Thickened oil escaped between the Veegarm and the hull.

RECOMMENDATIONS

Most of the failure mechanisms can be lessened at least to some degree with modifications to the skimming arm. Any modifications which are considered, however, should take the existing structural integrity of the Veegarm into account.

The vortices formed can probably be reduced by simply eliminating the abrupt change in the angle of attack of the weir. The flotation would need to be adjusted to retain buoyant stability. The losses between the Veegarm and the hull of the support craft can be virtually eliminated by using a water jet or series of water jets at this location (See Breslin, M. K.,[3] Using Coherent Water Jets to Control Oil Spills). Any inboard arm extensions will complicate the launch/retrieval methods without necessarily improving the butted junction. High pressure water for powering the jets could be supplied by the support craft in order to limit the complications involved with a water pump on the arm itself.

Wave reflections are probably less of a problem than the tests indicate. Sea conditions will generally provide longer wavelengths than the 1.9-m wave used for one of the regular wave tests. The proven ability of a series of water jets to divert oil slicks while not reflecting waves should be investigated as an alternative to the solid face in the event that the Veegarm would need to be towed into such conditions, but this should be viewed as a low-priority modification.

The most important area of any redesign consideration, based on this testing, should be the inboard pontoon. The classic boom-type failure that occurs here at the higher speeds tested can be attributed to several factors. Investigation of the abrupt intercept angle and minimum draft at the point where the oil is thickest is necessary. It is doubtful that the losses can be eliminated because of the basic nature of the boom structure.

RIGGING

An exact duplication of the physical geometry of the Veegarm as used in commercial applications was not possible. A typical support vessel is 21-m in length and would have a draft of 1.1 m. OHMSETT is capable of accommodating such a vessel but the logistics and cost for trans-Atlantic transport was prohibitive. A 9-m vessel was substituted for the 21-m support craft and the arm was tested without the oil-water separating capabilities contained within the standard support vessel. The substitute craft thereby served only as a hull to block the excessive spreading of oil. Because of the smaller length overall of the substitute vessel, the towing arrangement was slightly altered to accommodate the arm. For testing purposes, the arm was rigged so that the tow point used for the outboard pontoon was the main bridge rather than the bow of the support vessel. The inboard pontoon was loosely fastened to a wire rope choker wrapped around the hull of the substitute craft. The choker was tight enough to hold the Veegarm butted against the hull but free enough to respond independently to the waves. The outboard pontoon was secured to three locations. The pontoon was linked to the towing bridge and the barge to simulate the usual attachment to the bow of the 21-m support vessel. The third attachment was to the

[3]Breslin, M.K. 1981. Using Coherent Water Jets to Control Oil Spills. EPA-600/2-81-141.

auxiliary bridge. It was used to control the skimming arm during the tow back phase of each test. The barge was attached to the towing and auxiliary bridges as well. The pump discharge was fitted with a 152-mm (6 inch) hose that was, in turn, connected to the auxiliary bridge oil recovery tanks. The hydraulic power pack was positioned on the east side of the auxiliary bridge. The rigging for the Veegarm is shown in Figure 25. The data obtained is indicative of the performance as tested. The reader is cautioned of possible interactions with the support vessel that could effect performance.

DESCRIPTION OF TESTING

The Veegarm primary tests incorporated four distinct independent variables, after a short series isolated the optimum pump rate. A total of 55 tests plus shakedown and rigging stability runs was conducted. The Veegarm was towed into the waves (if used) in all tests.

In order to maintain technique consistency, a standard procedure was followed throughout the test program. The test results are indicative of changes in test variables and not changes in test procedure. The test sequences followed the pattern below.

1. Establish oil distribution rate in re-irculation mode.
2. Create wave pattern as outlined in the test matrix.
3. Bring Veegarm to designated tow speed.
4. Begin oil distribution onto the water.
5. Start oil collection pump onboard the Veegarm and make observations during steady-state portion of the tow.
6. Stop oil distribution.
7. Stop wave generation.
8. Control lost oil.
9. Bring Veegarm to complete stop.
10. Drop tow-back booms and return to starting point.
11. Measure collected fluids.
12. Strip excess free water.
13. Measure remaining fluid.
14. Sample remaining fluid.
15. Prepare for the next test.

The length of time available for oil distribution and collection was limited by the tank length and auxiliary bridge recovery tank storage. On higher speed tests in

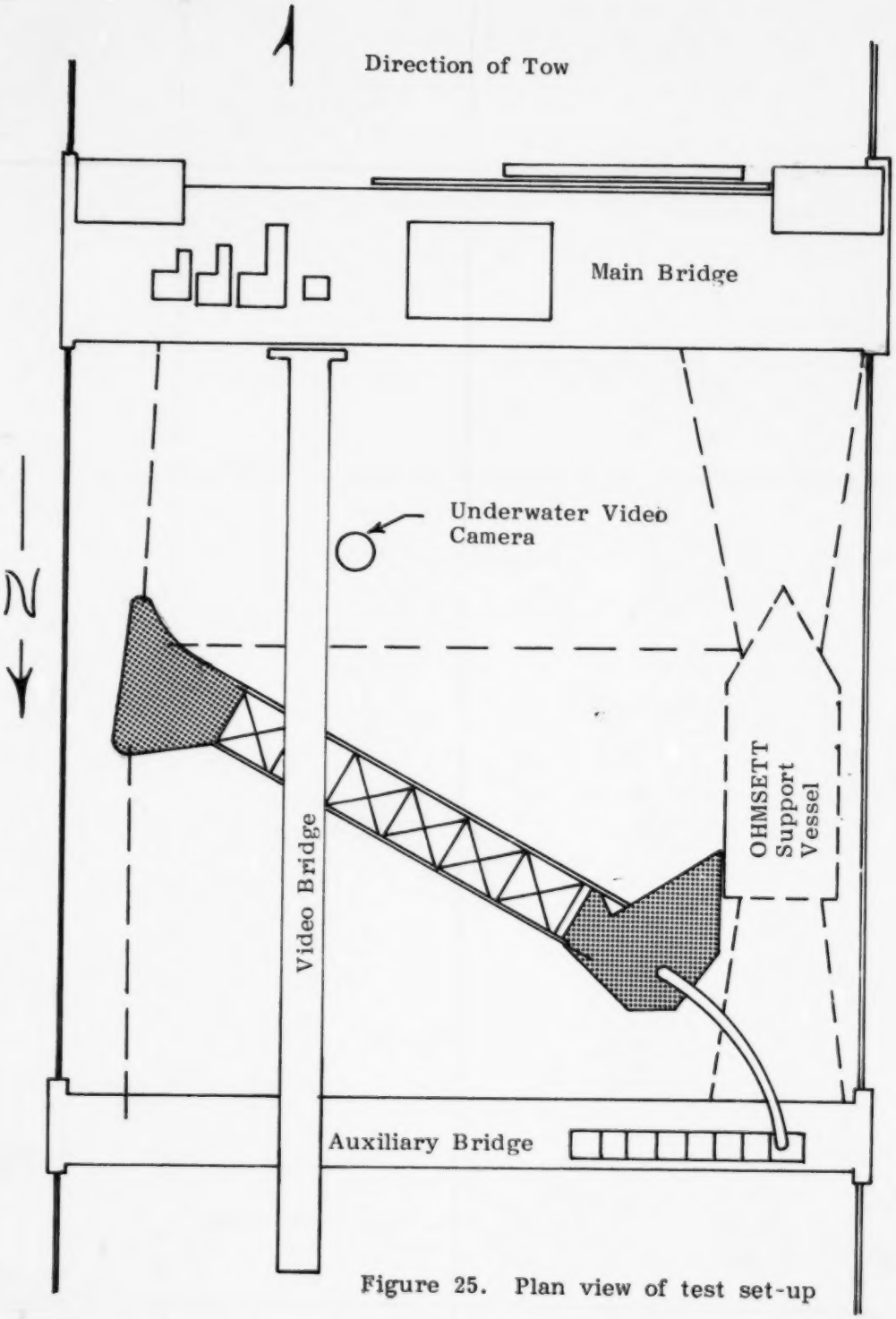


Figure 25. Plan view of test set-up

waves, steps five and six were often reversed because of the additional time required for the slick to reach the weir and the test-time limitations of a finite tank length.

The stripped, collected fluids were sampled using a stratified sample thief in the auxiliary bridge collection tanks. The sample was analyzed on-site for oil content using the toluene centrifuge method outlined in ASTM D1796-75.

TEST RESULTS

Throughput efficiency (TE) is defined to be the ratio of the volume of oil recovered to the volume that was encountered. During some of the slow speed tests, the TE is calculated to be greater than 100%. Clearly this is not a physical possibility; more oil cannot be recovered than is available for recovery. This may have been caused by any of three principal sources. First, small volumes of oil from previous tests occasionally were in the intercept width of the arm. Second, the weir, pump, and hose generally still contained oil from the previous test. Third, there is an inherent error introduced by sampling and analyzing small volumes of oil in large volumes of skimmer discharge. The excessive values have been reported as 100% in all such cases.

Recovery efficiency (RE) is defined as the ratio of the volume of collected oil to the volume of collected liquid. In every test, the RE varies from collection compartment to collection compartment within the segmented auxiliary bridge recovery tank. Generally, the RE had its lowest values at the beginning and ending compartments, with the maximum located somewhere between these two. The maximum RE is given for each test in this report. Figure 26 graphically represents the time-RE relationship for tests 29, 33, and 97. (Note that the scale used for RE values for the Veegarm is not 0 to 100%.) The general trend of all the tests is shown by tests 29 and 33. Test 97 was run to confirm that the RE could remain consistent if there were no oil accumulation period at the start of a test or oil depletion period at the end of a test, and to determine the maximum RE obtainable. A very thick slick (10 mm) was distributed and allowed to build at the weir before collection began. Distribution continued until all the recovery tanks were filled leaving approximately a 0.5-m^3 slick remaining on the water surface. This demonstrates that the RE will remain nearly constant and near the maximum in operation if a steady oil slick is encountered by the arm. In all cases, the RE is given as the maximum RE obtained during that particular test.

Oil recovery rate (ORR) is defined as the rate at which oil is removed from the water surface. The ORR given is the average value, or the total volume of collected oil divided by the entire time interval for collection. ORR is treated in this fashion because small variations in pump speed can create dramatic and unrepresentative changes in the given recovery rates.

Calm Water Tests

Calm water tests were run at various tow speeds up to 3 knots using 1-, 2-, and 5-mm slick thickness. At speeds of up to 1 knot the Veegarm has a 100% TE. At speeds greater than 1 knot, the TE decreases. The largest decrease occurs with the thickest slick as shown in Figure 27. The cause for this decrease appears to be boom type entrainment occurring principally at the inboard pontoon. When the contained oil slick reaches the inboard pontoon, there are numerous factors working against the collection of oil. The angle to the current is highest, the oil is thickest, and the draft is at a minimum. All of these factors hinder containment and eventual collection of

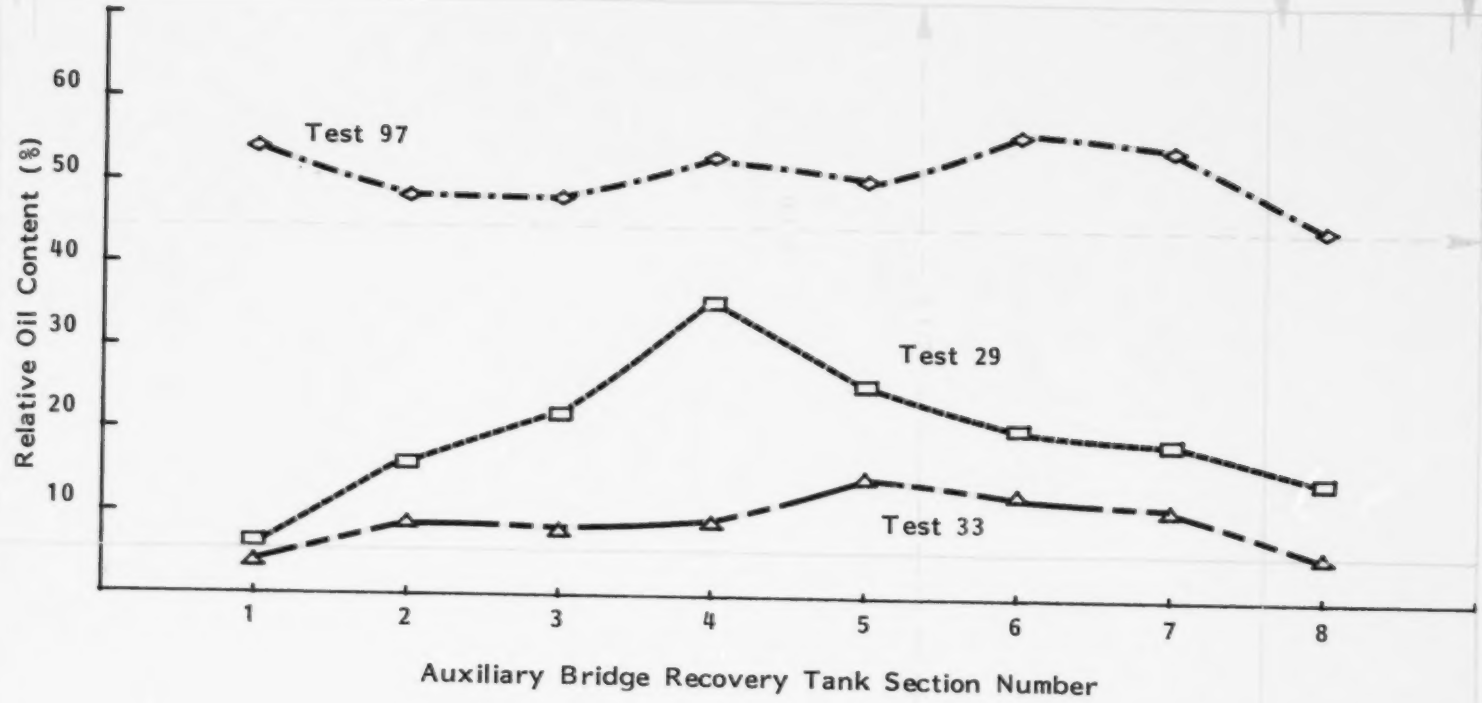


Figure 26. Real time analyses of the Recovery Efficiency for the Veegarm. Test 29 and 33 were run in calm water with 2-mm slicks of heavy oil. Test 97 was run to confirm that the Recovery Efficiency would remain essentially constant if sufficient oil was available. It also shows what is thought to be the maximum Recovery Efficiency obtainable with the Veegarm.

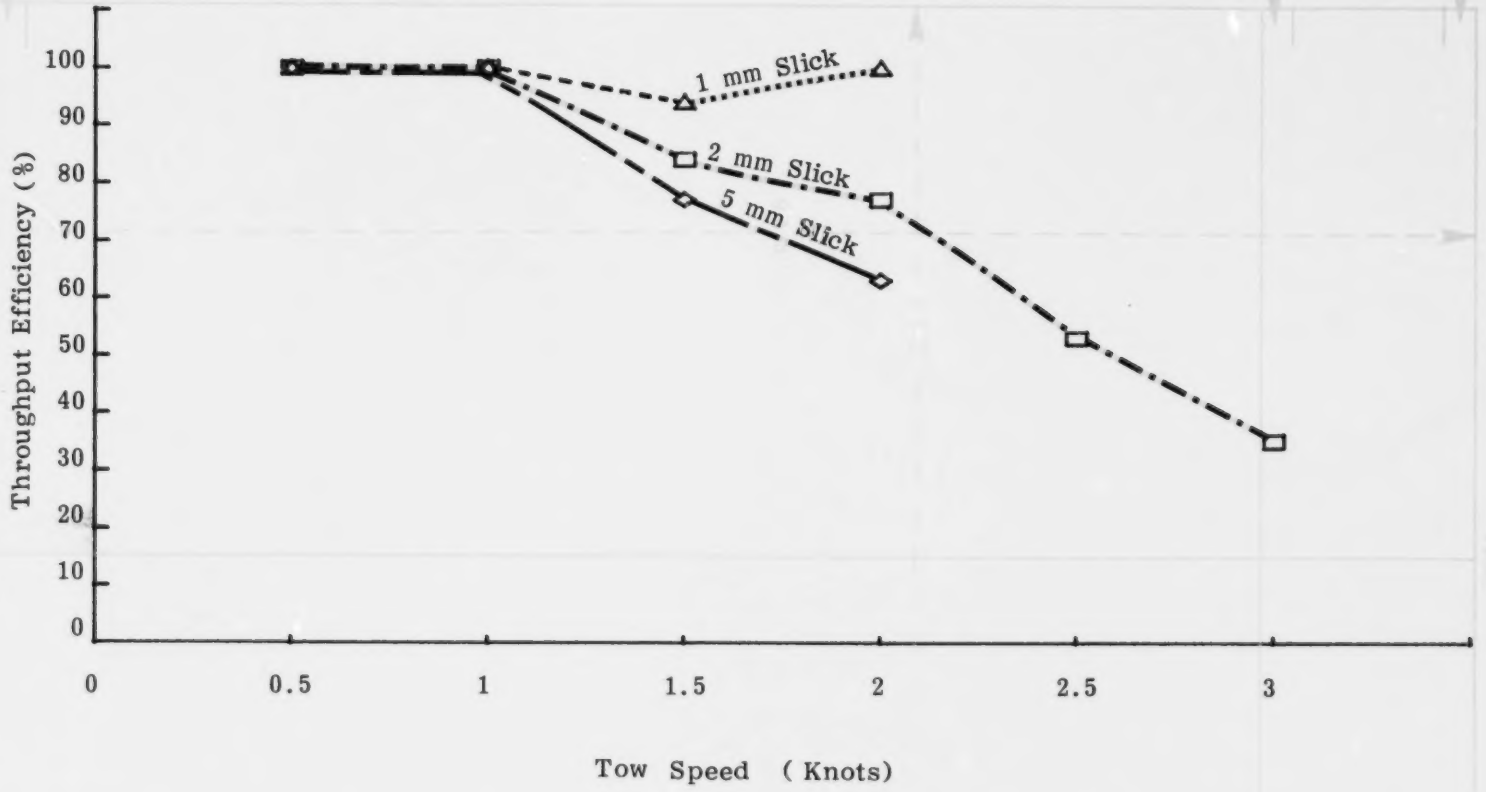


Figure 27. Throughput Efficiency of the Veegarm at tow speeds through 3 knots. The device had 100% Throughput Efficiency in all three slicks through 1 knot and then decreased with increasing tow speed. The decrease was most rapid in the thickest slick.

oil. A second apparent loss mechanism was the vortices formed at the edges of the weir, which drive the oil into the water column. Although this loss mechanism clearly occurs, the majority of the loss can be attributed to the boom-type loss, especially at speeds greater than 2 knots. The boom-type loss is clearly shown in Figure 28.

RE and ORR, unlike TE, increase with increasing slick thickness. Using a 5-mm slick, RE peaks at 40% between 1.0 and 1.5 knot. The 2-mm slick produces a maximum RE of approximately 25% between 1.5 and 2.0 knots. The 1-mm slick produces the best RE at 1.0 knot. The maximum RE is obtained with thinner slicks at slower speeds as shown in Figure 29. The ORR exhibits an interesting behavior. In all three slicks, the ORR shows a local minimum at 1.5 knot (see Figure 30).

The Veegarm was tested in calm water using a 2-mm slick of light oil. TE is again at 100% for tests through 1 knot. At a speed between 2.0 and 2.5 knots, the TE falls off dramatically to approximately 30%. It was only during the calm water run of 2 knots that oil loss from under the boom section of the arm was noticeable, in addition to the losses at the weir. A comparison of the TE results for light and heavy oils is shown Figure 31.

The RE seems to reach a low point at 1.5 knot at 8% after a maximum of 27% was obtained at 1 knot. The ORR also seems to fail at 1.5 knot between two local maximums of 20 and 25 m^3/hr at 1 and 2 knots, respectively. The minimums are shown in the tow speed graphs, Figures 32 and 33, the performance in a 2-mm slick of heavy oil is also given for comparison. In most cases the Veegarm performs better in slicks of heavy oil. The physical properties of both Circo 4X light and Circo X heavy oil, which were used as test fluids are summarized in Table 7.

Regular Waves

The Veegarm was tested in regular waves 1.9-m long by 0.19-m high and 12-m long by 0.20-m high. The shorter wave was reflected from the arm and the barge (see Figure 34) and collided with incident waves to establish a chop in the contained area of the "V". This chop tended to prevent the oil from reaching the weir for collection. This accounts for the generally low TE in this wave condition. The Veegarm responded better in the longer (12-m) wave. In this wave, the Veegarm produced essentially the same TE as in calm water. The TE for the longer wave is compared with that of the Veegarm in calm water and in the short wave in Figure 35.

The chop within the "V" resulting from the short wavelength drove almost only water into the weir, giving a maximum RE of 10% at 1 knot and an ORR of 11 m^3/hr as shown in Figures 36 and 37. The longer waves drive excess water into the weir as well, but to a lesser degree, since the arm can respond to the changing height of the water. Both RE and ORR reached maximums at 1.5 knot of 20% and 20 m^3/hr, respectively, as shown in Figures 36 and 37.

Harbor Chop Tests

A series of tests was designed to give a comparison of the arm's performance in a 0.19-m harbor chop using both heavy and light oil. The Veegarm performed better with the heavier oil and generally better at lower speeds. The TE in both cases begins with a maximum at 0.5 knot and rapidly decreases with increasing speeds. A graphical comparison of the TE for light and heavy oil in a 0.19 m HC is shown in Figure 38. Similarly, the RE begins at a maximum and decreases with speed. The light oil RE was

Figure 28. Classic boom-type losses developed near the Veegarm weir at higher tow speeds. Notice that the entrained oil is concentrated directly behind the inboard pontoon containing the weir.

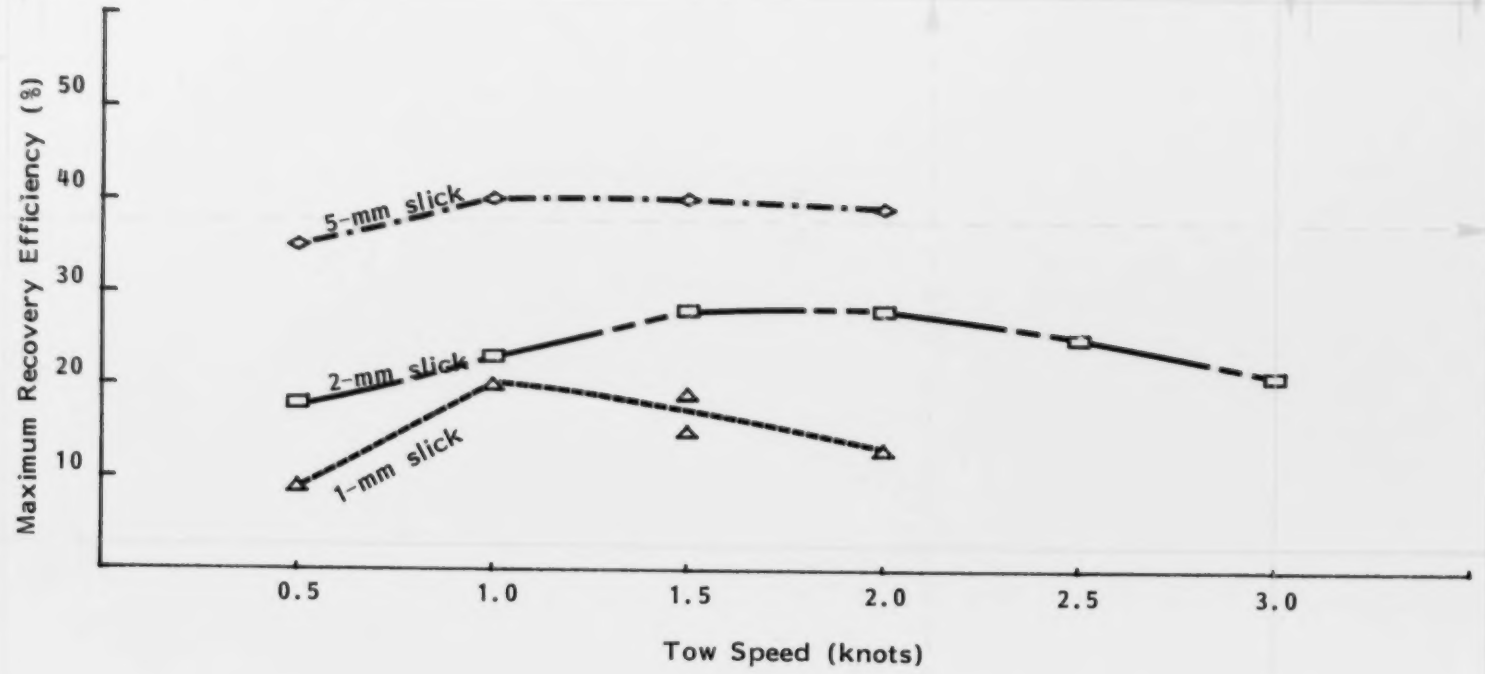


Figure 29. Recovery Efficiency of the Veegarm in calm water at varing tow speed and slick thickness. The recovery Efficiency is greatest with the thickest slick.

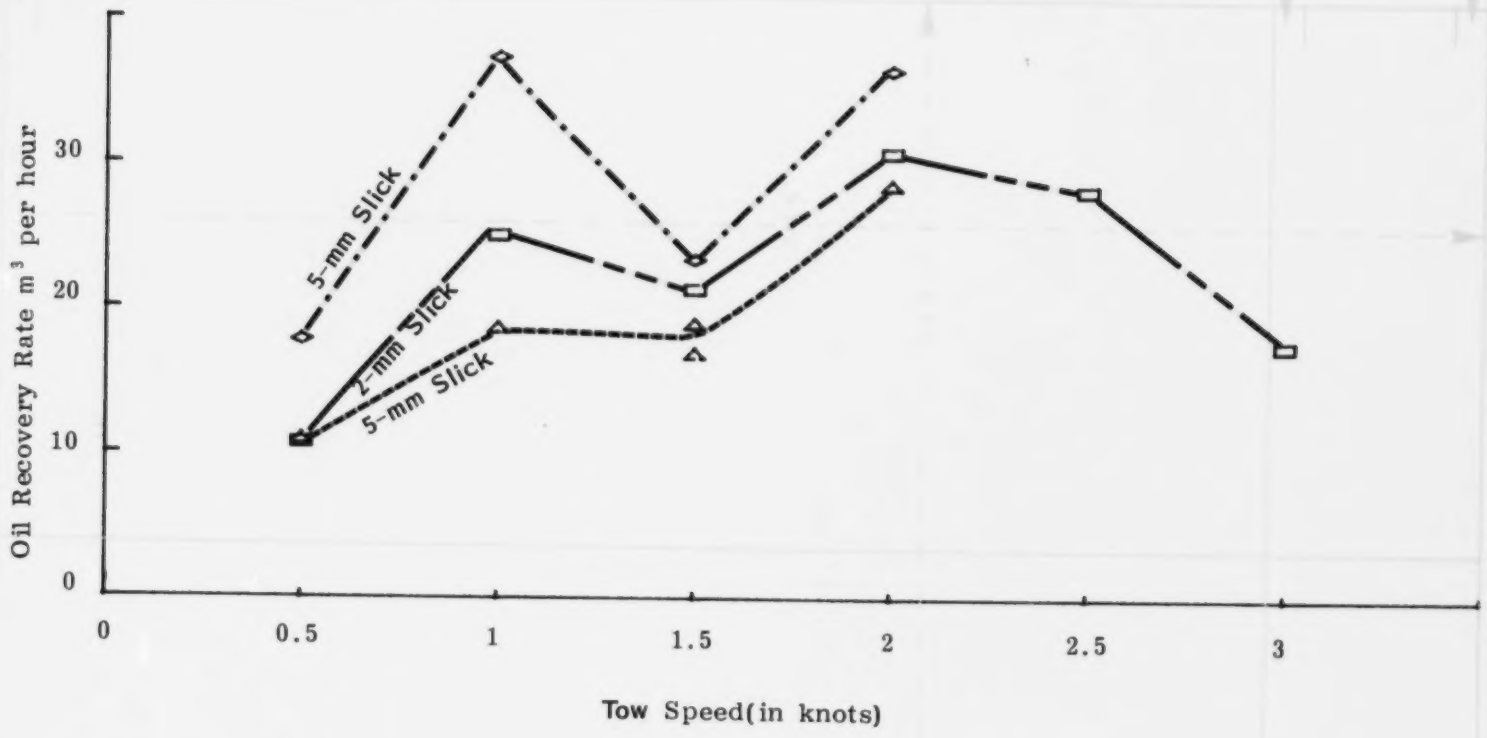


Figure 30. Tow Speed oil recovery rate trends for the Veegarm in three slick thicknesses. Notice the local minimum at 1.5 knots for all three thicknesses. The Oil Recovery Rate is higher with thicker slicks than with thinner slicks.

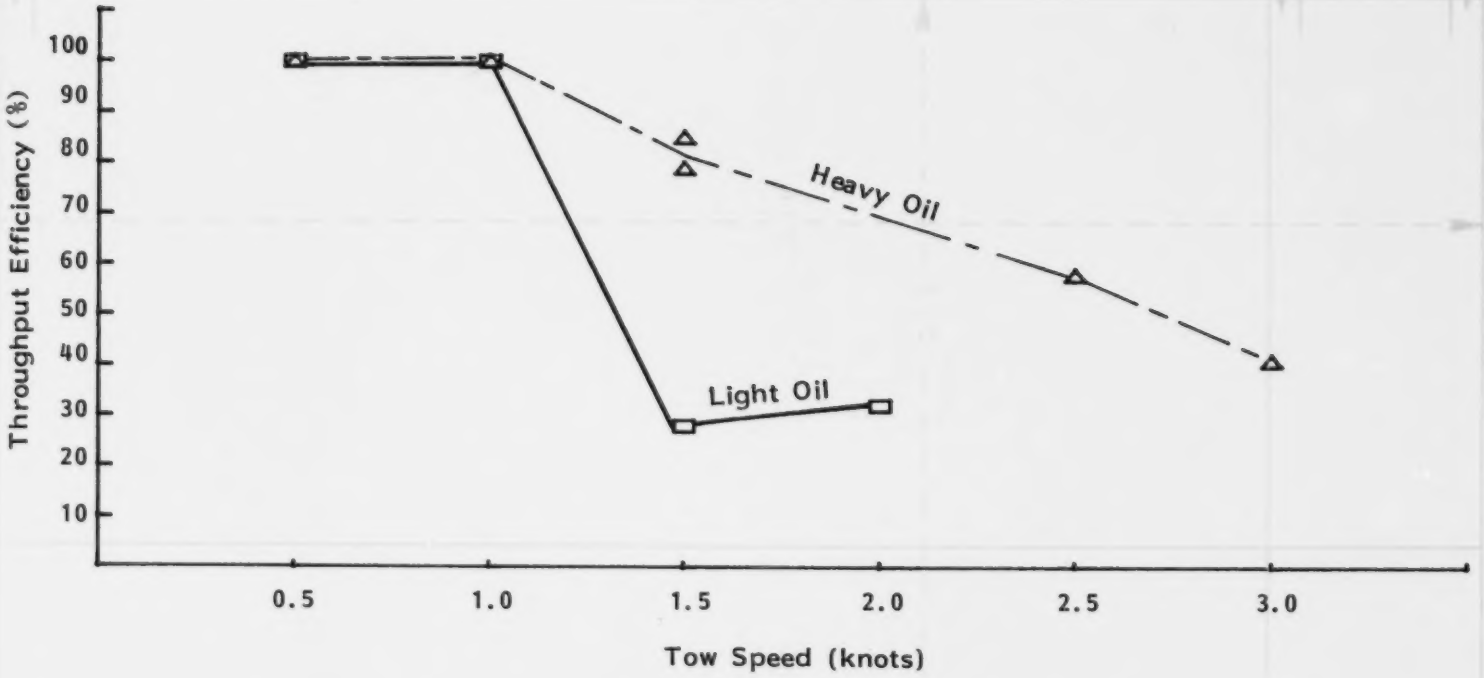


Figure 31. Comparison of the Throughput Efficiency of the Veegarm in slicks of heavy and light oil. All the tests were run in calm water using 2-mm slicks.

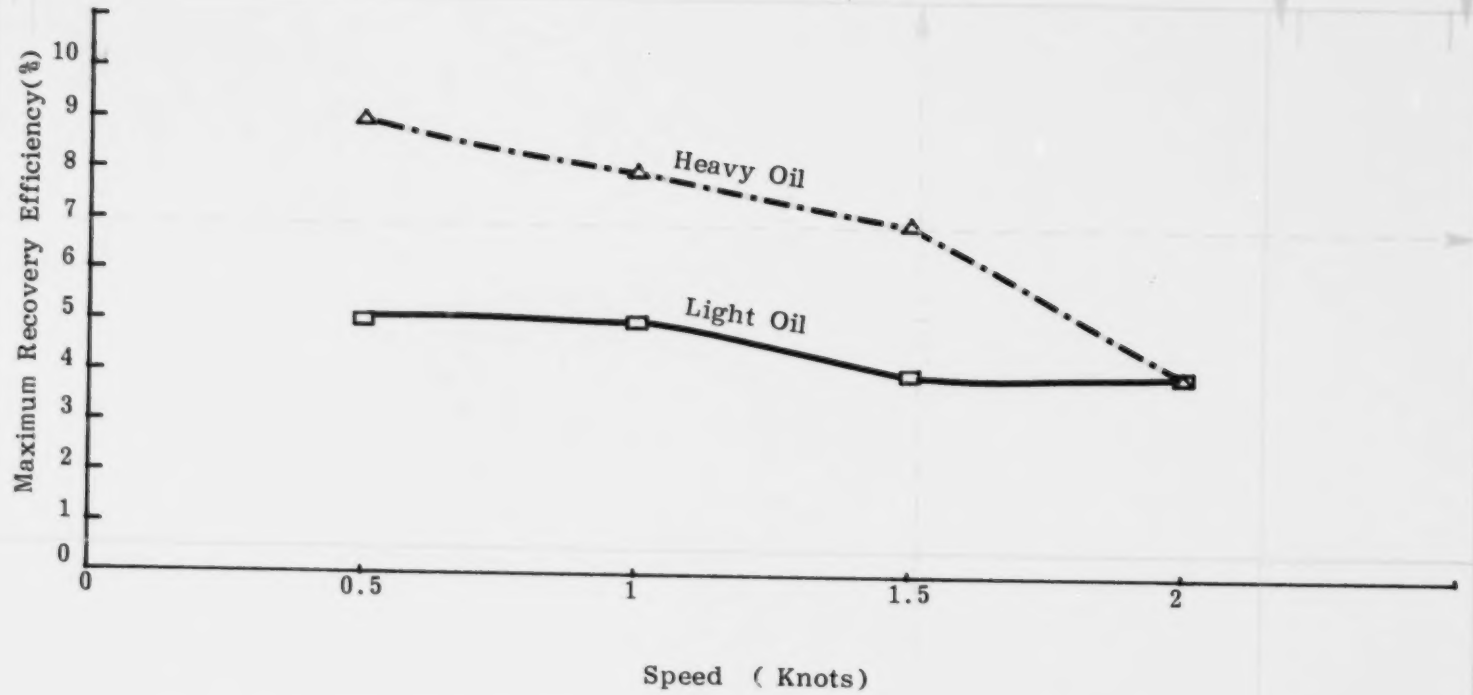


Figure 32. The Recovery Efficiency of the Veegarm was superior when tested with heavy oil. These tests were run in calm water using 2-mm slicks.

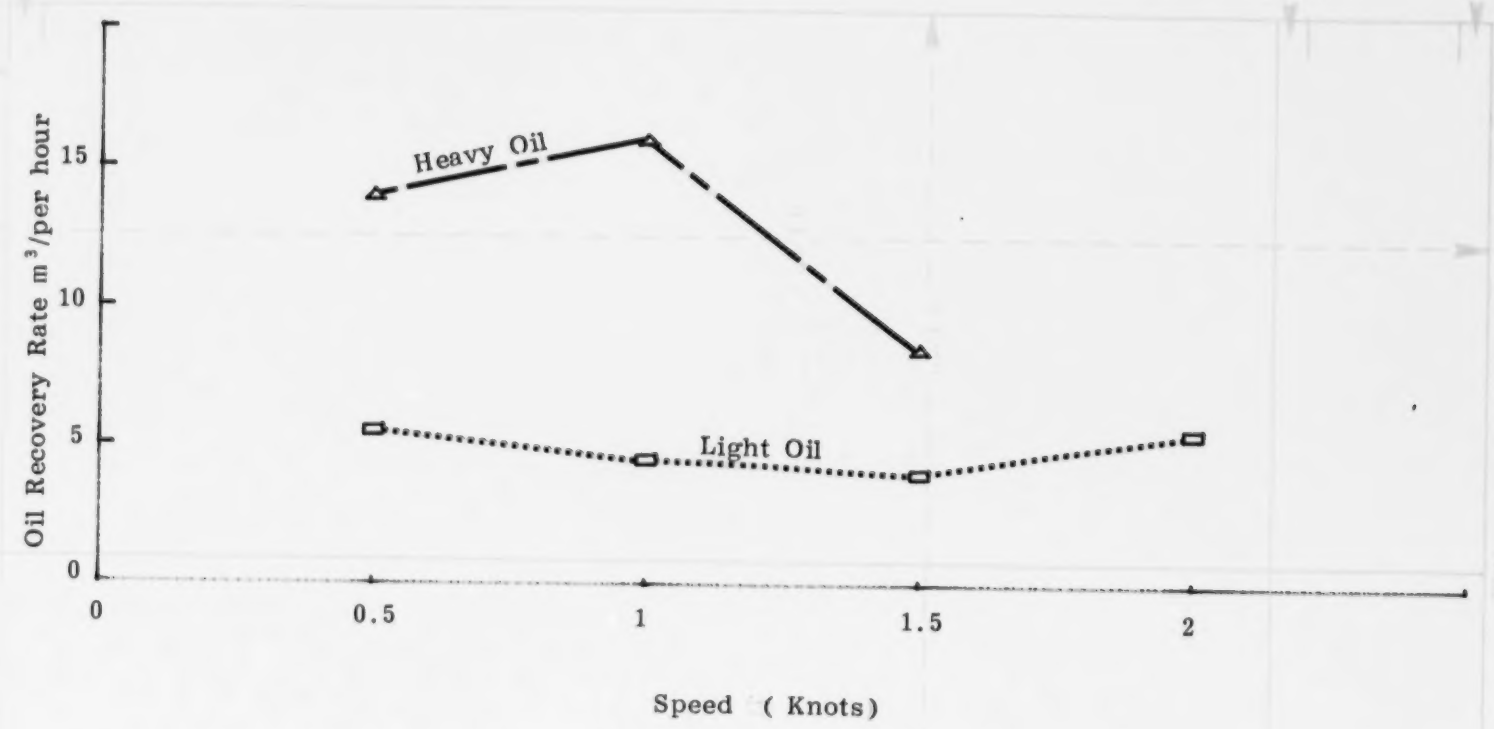


Figure 33. The Oil Recovery Rate of the Veegarm was higher when tested with the heavy oil. These tests were run with 2-mm slicks in calm water.

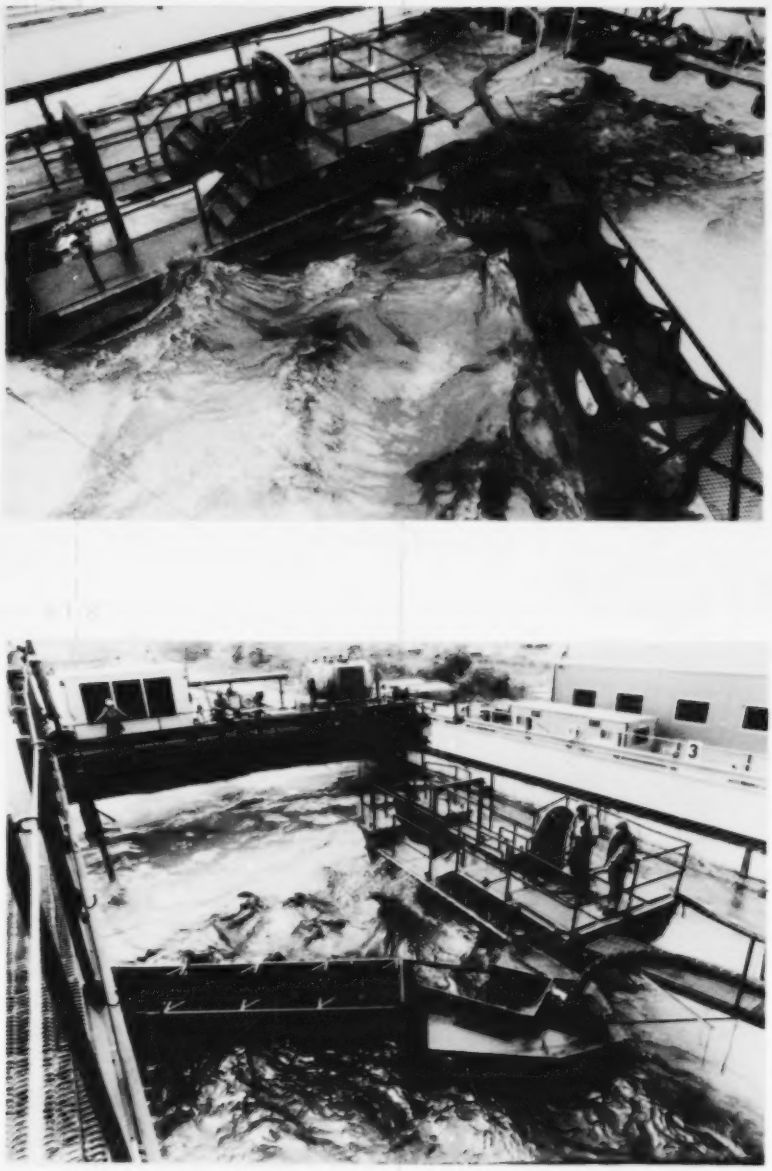


Figure 34. The Veegarm is shown under test in the 1.9 m-long wave. The reflection of the incident wave is shown above, and the resulting chop which developed in the "V", below.

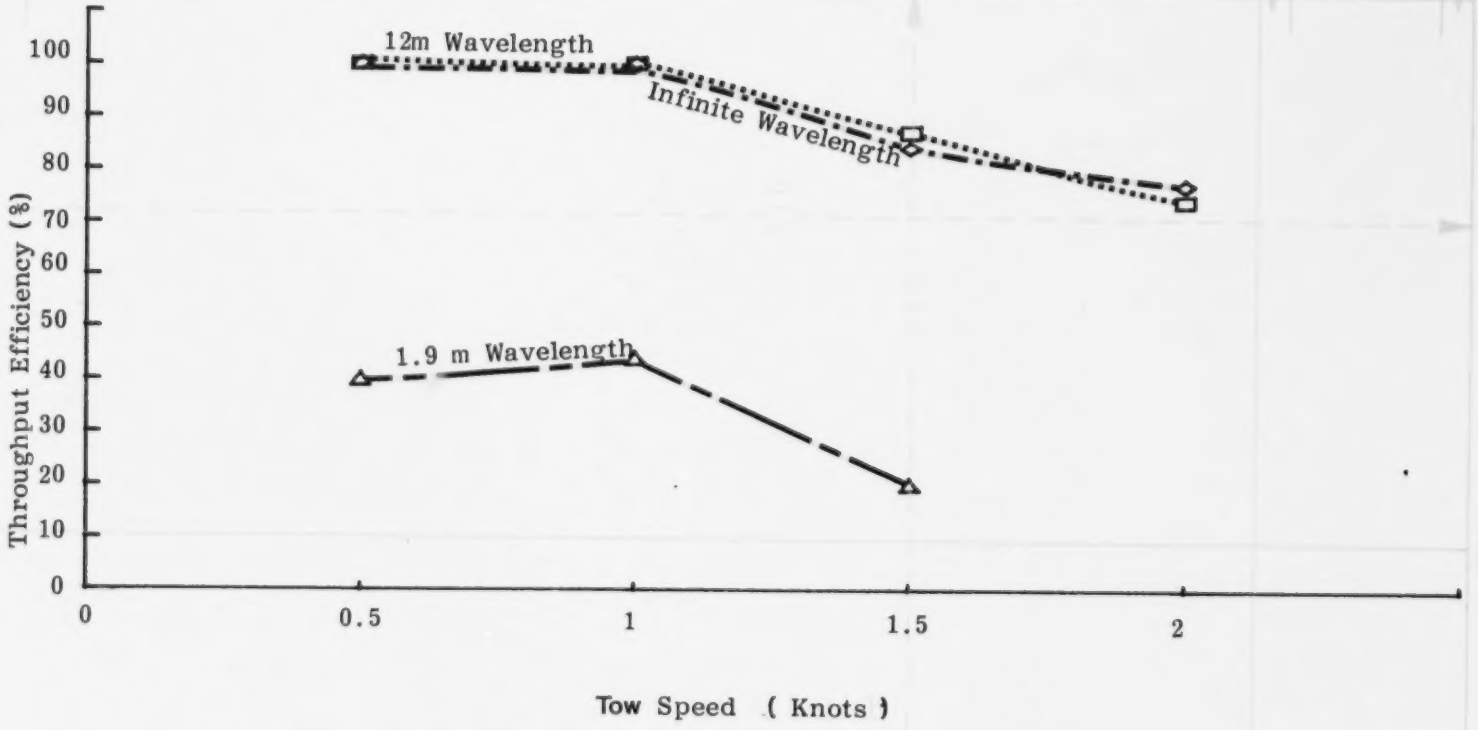


Figure 35. Comparison of the Throughput Efficiency of the Veegarm in the two regular waves with the calm water performance. The TE in the 12-m long wave was essentially the same as that in calm water.

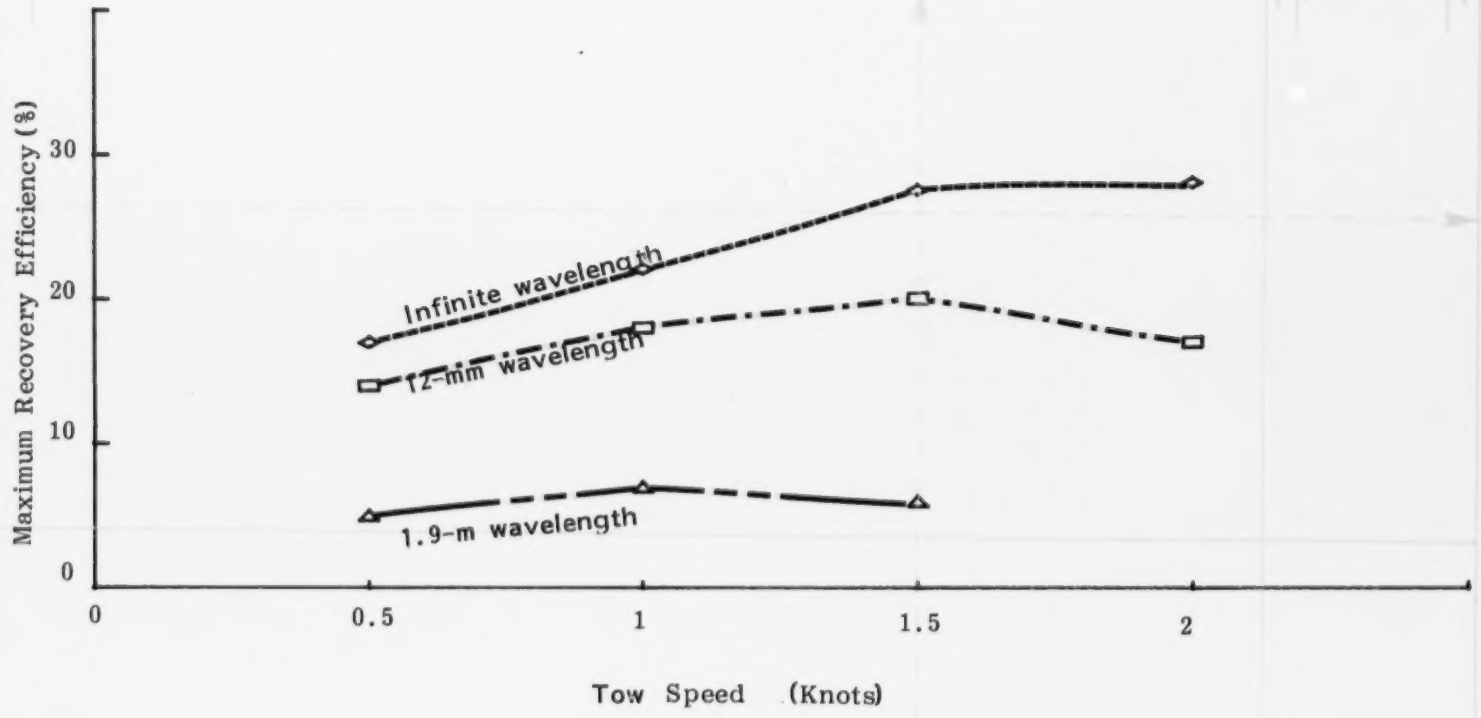


Figure 36. Recovery Efficiency of the Veegarm in regular waves compared to that in calm water (Infinite wavelength). The inability of the Veegarm to respond to the shorter wave drove excess water over the weir, lowering Recovery Efficiency.

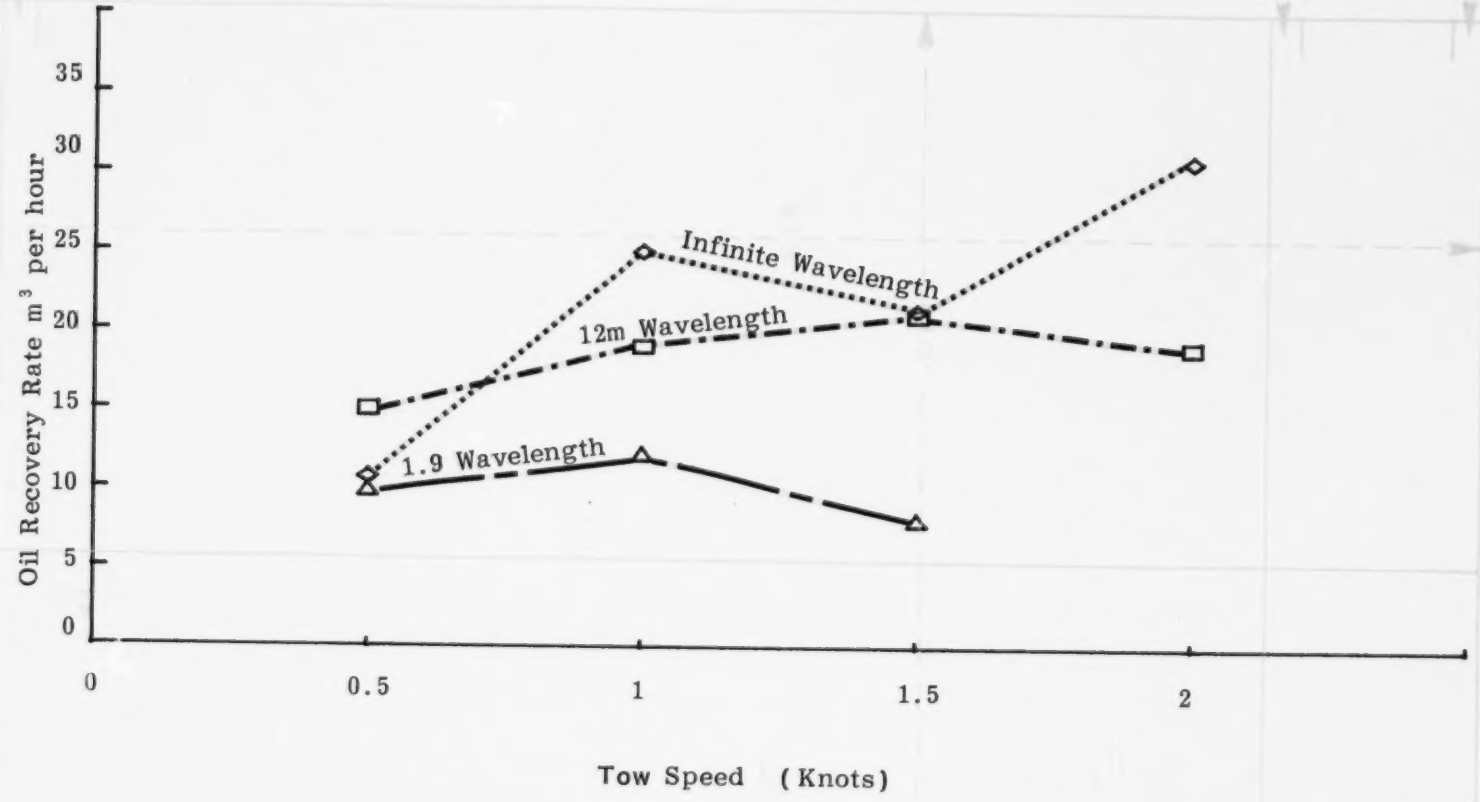


Figure 37. Comparison of the Oil Recovery Rate of the Veegarm in the two regular waves with the calm water performance. Although the Oil Recovery Rate is higher in the 12-m wave at 0.5 knots, the Recovery Efficiency is lower (see figure 36). The wave action drove fluids into the weir, including excess water.

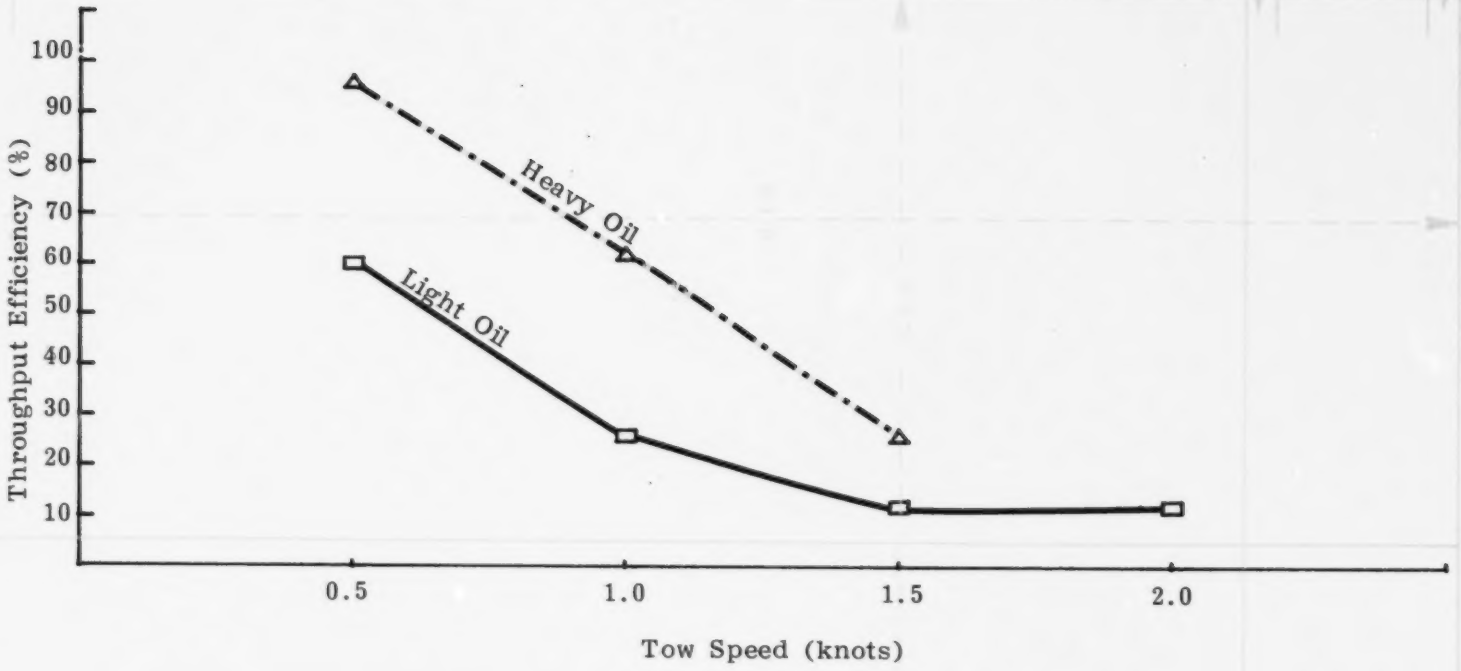


Figure 38. Comparison of the Throughput Efficiency of the Veegarm in light and heavy oil. The tests were run in a 0.19-m Harbor Chop using 2-mm slicks.

generally only half of that achieved with heavy oil, as shown in Figure 39. In this harbor chop, the ORR as the only rating criterion that was not monotonically decreasing with tow speed and gave a maximum at 1 knot of 16 m^3/hr with heavy oil. The light oil ORR was essentially constant at 5 m^3/hr. The results are graphed in Figure 40, showing the comparative results of heavy oil with light oil.

Four series of HC tests were conducted using 2-mm slicks of Circo X-heavy and Circo 4X-light oil. The heavier oil once again gave consistently better performance. The heavy-oil HC tests were conducted in 0.19-m and 0.40-m waves. The light-oil test series was run with 0.19-m and 0.63-m waves.

TABLE 7. PHYSICAL PROPERTIES OF LIGHT AND HEAVY OIL USED IN THE VEEGARM TESTS

Property	Circo 4X Light	Circo X Heavy
Interfacial gravity	0.94	0.89
Viscosity @ 29°C (cSt)	9.00	1,300.00
Surface tension (dynes/cm)	33.00	34.00
Interfacial tension (dynes/cm)	27.00	26.00

The viscosity of test oil was obtained at about 25°C using a Brookfield Model LVT viscometer and at 75°C using a Fisher/Tag Saybolt viscometer. The viscosity is converted to centistokes (cSt) using ASTM STP 43C. Surface tension and interfacial tension with test tank water was found using a Fisher Scientific Model Surface Tensiomat at room temperature. Specific gravities were obtained using a hydrometer. The percent water and bottom solids was determined using ASTM D1796-75.

The TE for the heavy-oil HC test series shows essentially identical performance at 0.5 knot for both wave heights. The TE drops off more quickly in the 0.40-m HC than it does in the 0.19-m HC. In light oil, however, the 0.19-m HC series shows a more rapid decrease than the 0.63-m HC after 60% maximums for both at 0.5 knot. These trends are shown in the graph in Figure 41. The Veegarm is shown under test in a 0.63-m HC, the largest wave used, in Figure 42.

The maximum RE was achieved by the Veegarm in the heavy oil slicks, and the 0.40-m HC. The RE with the heavy oil in the smaller chop does not drop off as rapidly. Light oil slicks gave RE values between 4 and 5% in both waves and at all speeds. The RE for all HC tests is below 10%. The Veegarm RE is graphed against tow speed for these tests in Figure 43.

The Veegarm gives better ORR values with the heavier oil and a maximum of nearly 16 m^3/hr at 1 knot in the 0.19-m HC. The remaining three series resulted in ORR values below 9 m^3/hr at all speeds. A summary of the ORR for this series of tests in these four series is presented in Figure 44.

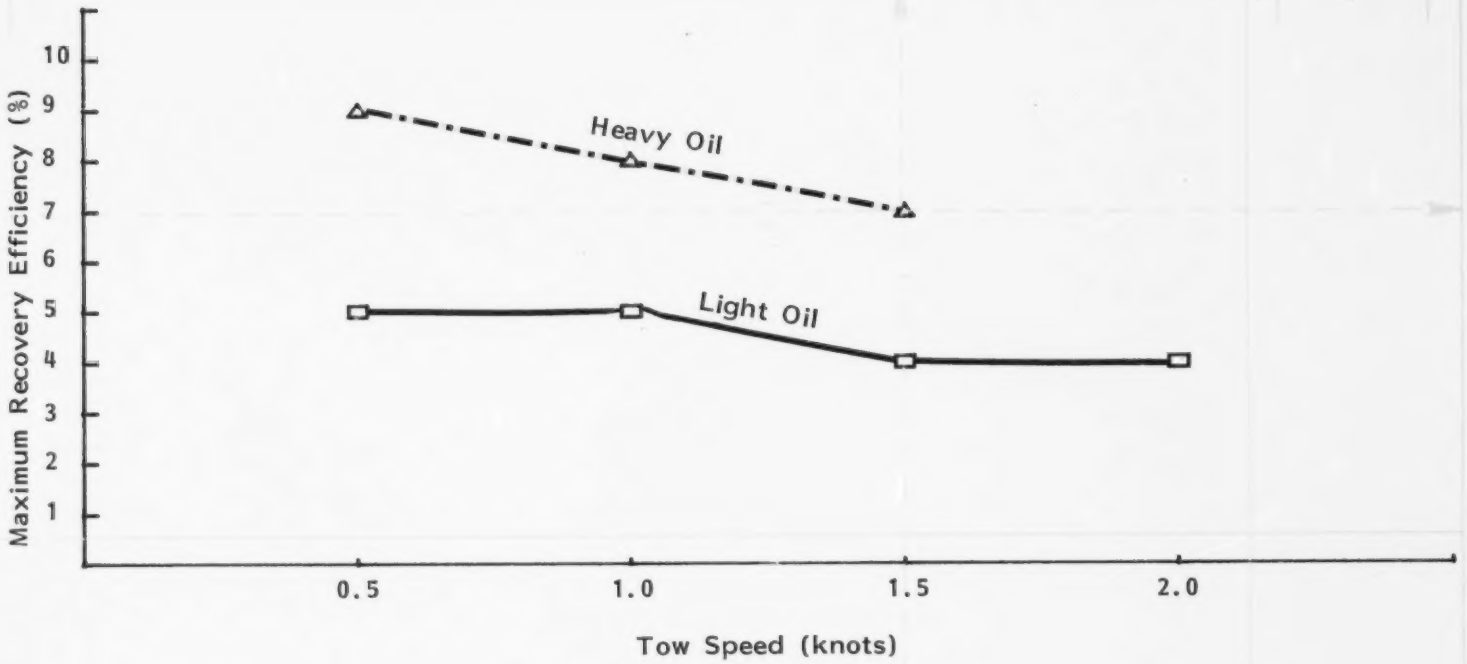


Figure 39. Comparison of the Recovery Efficiency of the Veegarm in heavy and light oils. Tests were run in a 0.19-m Harbor Chop with 2-mm slicks.

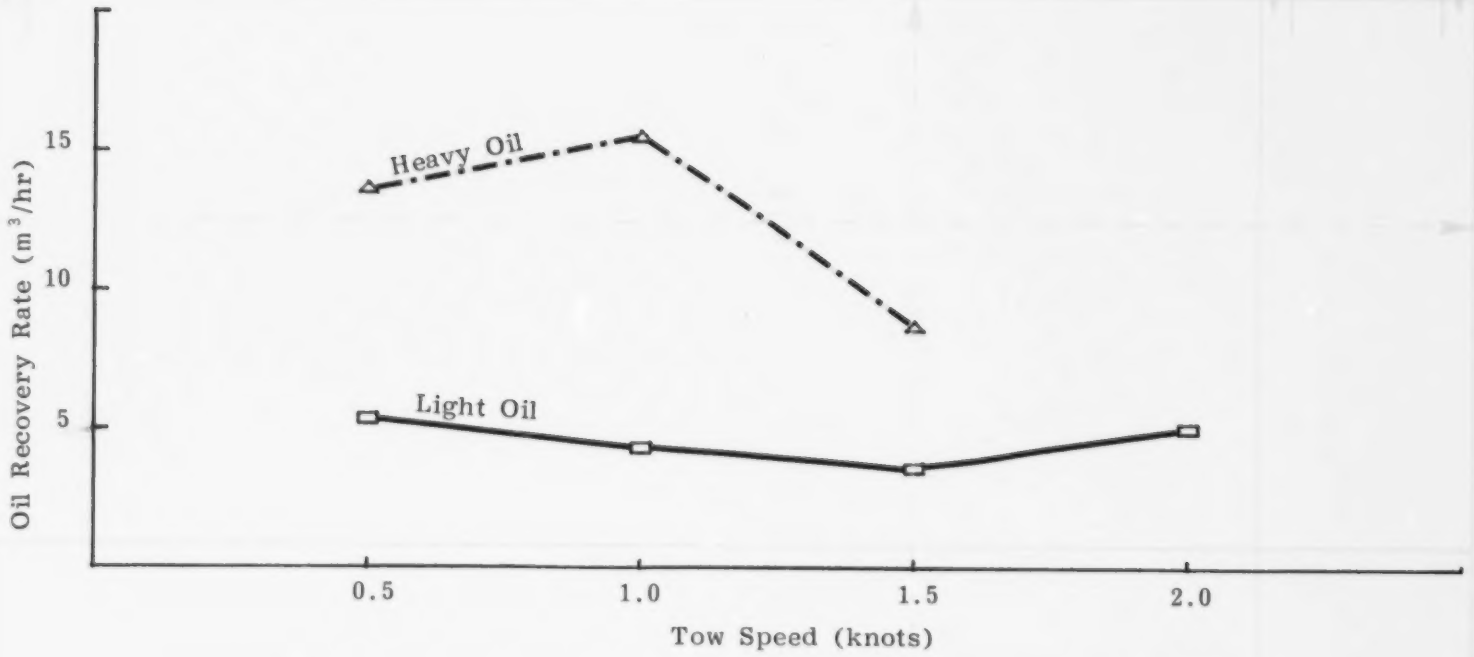


Figure 40. Comparison of Oil Recovery Rate for the Veegarm with heavy and light oils. The Oil Recovery Rate with heavy oil is higher between 0.5 and 1.5 knots. All seven tests were run in 0.19-m Harbor Chop with 2-mm slicks.

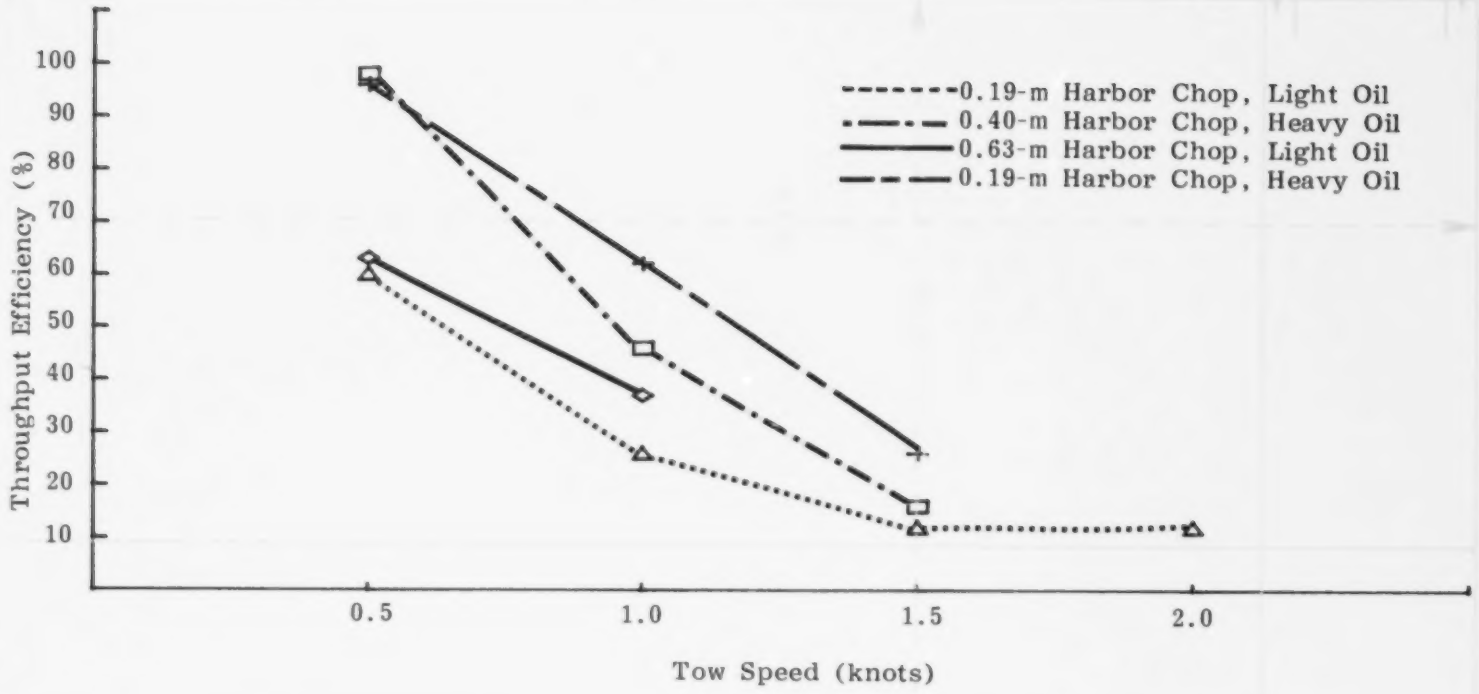


Figure 41. Throughput efficiency of the Veegarm in four harbor chops. The 0.19-m Harbor Chop was used with both heavy and light oil. Notice that while the Veegarm always gave better performance with heavy oil, the rate of decrease in throughput efficiency with tow speed is roughly equal.

Figure 42. Photograph of the Veegarm under test in a 0.63-m Harbor Chop. This was the only wave for which the outboard pontoon was exposed from the water or there was splashover. At no point during the testing did the bottom of the boom face leave the water surface.

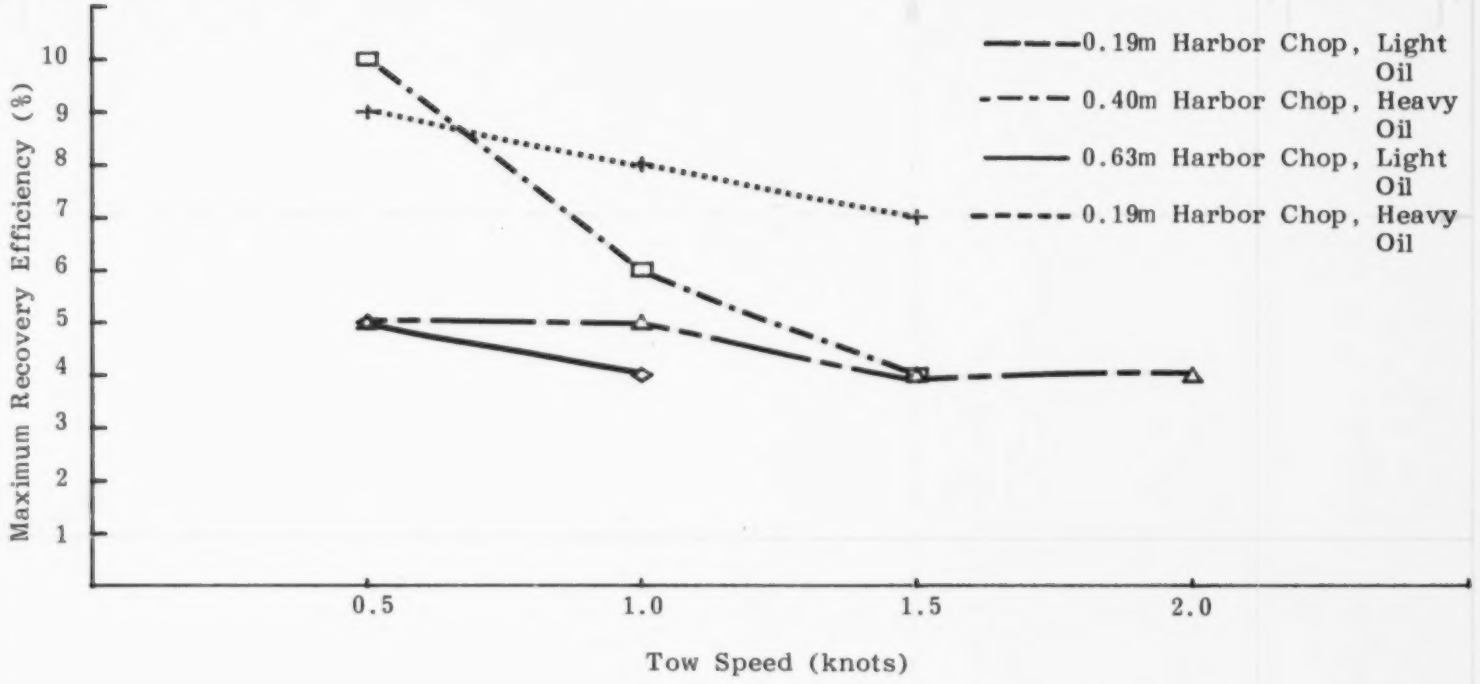


Figure 43. Recovery Efficiency of the Veegarm in harbor chops. Notice that while the Recovery Efficiency is higher in the 0.19-m harbor chop with heavy oil than with light oil, the rate of decline with increasing tow speed is nearly the same for each.

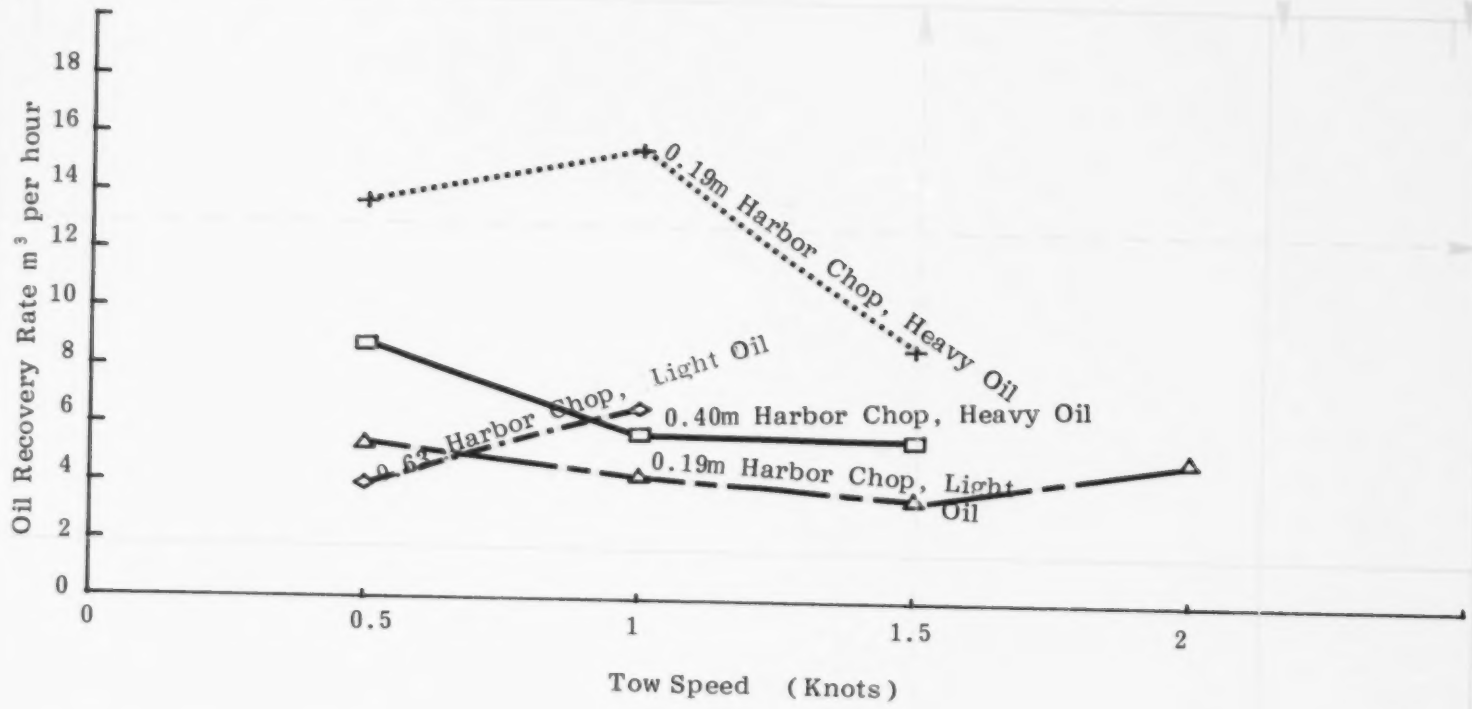


Figure 44. Oil Recovery Rate of the Veegarm in four Harbor Chops. The Oil Recovery Rate trends do not parallel those of the Recovery Efficiency. This is thought to be caused by the randomness of the wave patterns.

By choosing the smallest harbor chop the same height as the regular waves, a comparison of the two is possible without additional testing. In all cases, the Veegarm performs better in the 0.19-m HC than in the regular wave of the same height. This is true for TE and RE as well as ORR. The regular wave has a defined direction of travel, allowing the reflected waves in the "V" to build a more severe chop than is produced in the tank itself for HC conditions. The graphical comparison of the TE, RE, and ORR in these waves is given in Figures 45, 46, and 47.

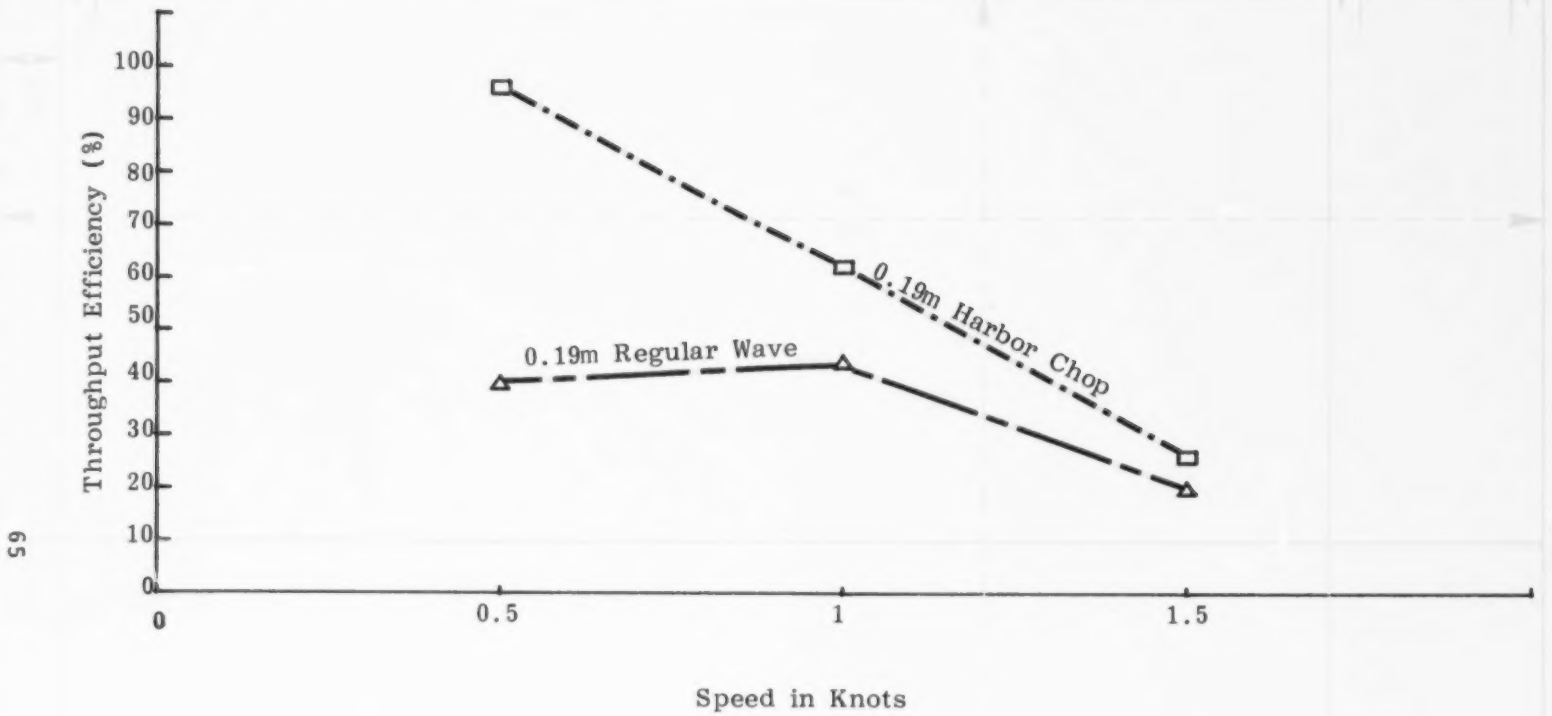


Figure 45. Comparison of the Throughput Efficiency for the Veegarm in a 0.19-m Harbor Chop with the 0.19-m regular wave. It felt that the chop that developed because of the wave reflection in the short wave was more severe than the traditional harbor chop, resulting in lower performance.

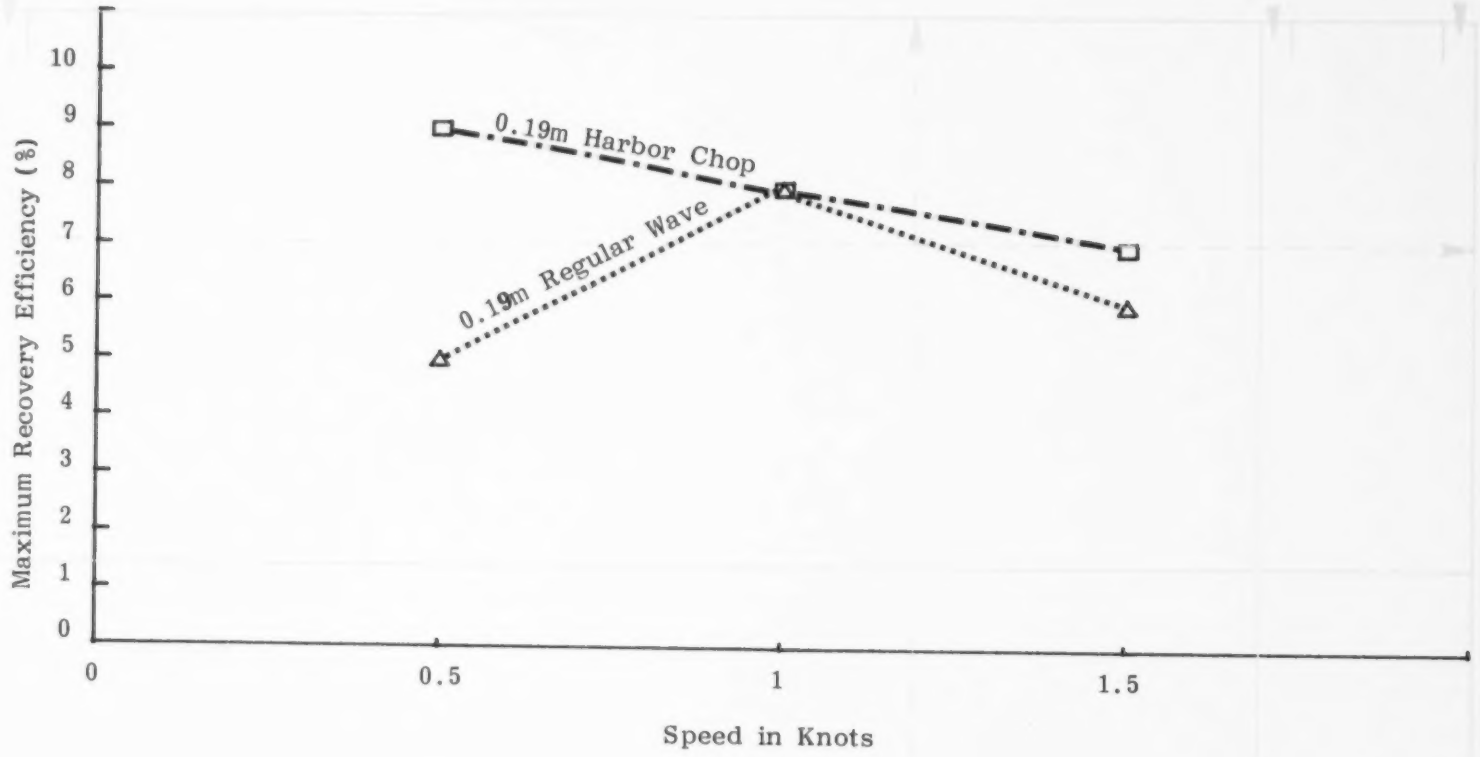


Figure 46. Comparison of the Recovery Efficiency of the Veegarm in a 0.19-m Harbor Chop versus 0.19-m Regular Wave.

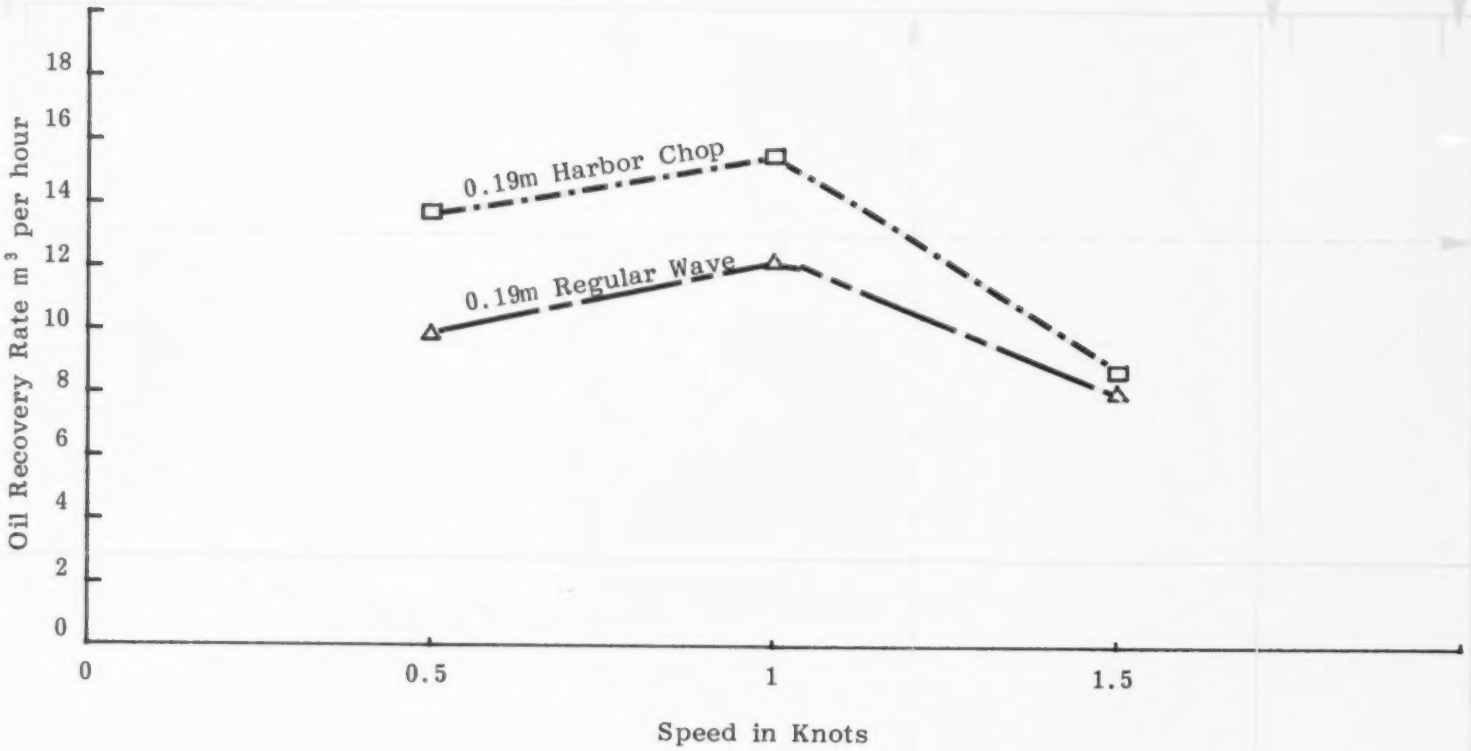


Figure 47. Comparison of the Oil Recovery Rate of the Veegarm in a 0.19-m Harbor Chop with that in a 0.19-m Regular Wave.

SECTION 4

SMALL BUSINESS PROGRAM

The OITC sponsored a three-week test program in November and December of 1980 that was aimed primarily at small businesses and private individuals who, for economic reasons, could not otherwise test at OHMSETT. The small business test program was publicized in several trade journals and newsletters. Those persons or companies with interest in the program were invited to apply for part of the test time available. The OITC screened the responses and selected three for testing based on promise and innovation. The three devices chosen for the testing were the Kebab 600, the Wylie skimmer, and the Skim-Pak Cluster. The Kebab 600 and the Skim-Pak Cluster were stationary skimmers, and the Wylie skimmer was an advancing skimmer.

The participants were responsible for the costs of shipping their devices to and from OHMSETT and for the costs incurred by their on-site technical consultants which the OITC required. All other costs for testing were paid by the OITC. This program, and others like it, provides useful information to both the businesses and the OITC. The private individuals receive the years of experience from OHMSETT, in addition to the quantified performance testing. They also receive practical information on the correct state-of-the-art, recommendations of the staff,and, perhaps most importantly, an opportunity to observe their equipment at work. The OITC receives an appraisal of the current state of development work in the private sector not only from the testing but also from the concepts presented in the many imaginative designs not selected for testing.

KEBAB 600

The Kebab 600 is the smallest of a family of disk skimmers marketed by Vikoma International Ltd. The unit tested came with two options: a 72-liter floating reservoir, and a small hand pump. The Kebab 600 weighs 12 kg and could have been positioned by a single man. The housing is constructed of marine-grade aluminum that encloses five stainless steel disks 278 mm in diameter. The rotating disks are wiped by Teflon (PTFE) scrapers. The collected oil runs into a trough for ultimate removal. The disks are driven by a variable-speed 24-watt DC motor. The unit tested functioned throughout the test period without mechanical problems. The marine design was adequate for the only wave used for testing (0.19 m). The Kebab 600 is shown in a line drawing in Figure 48.

The unit tested was provided by Strauss Engineering, Mason, New Hampshire. Mr. William Strauss was the technical representative and remained on site throughout testing.

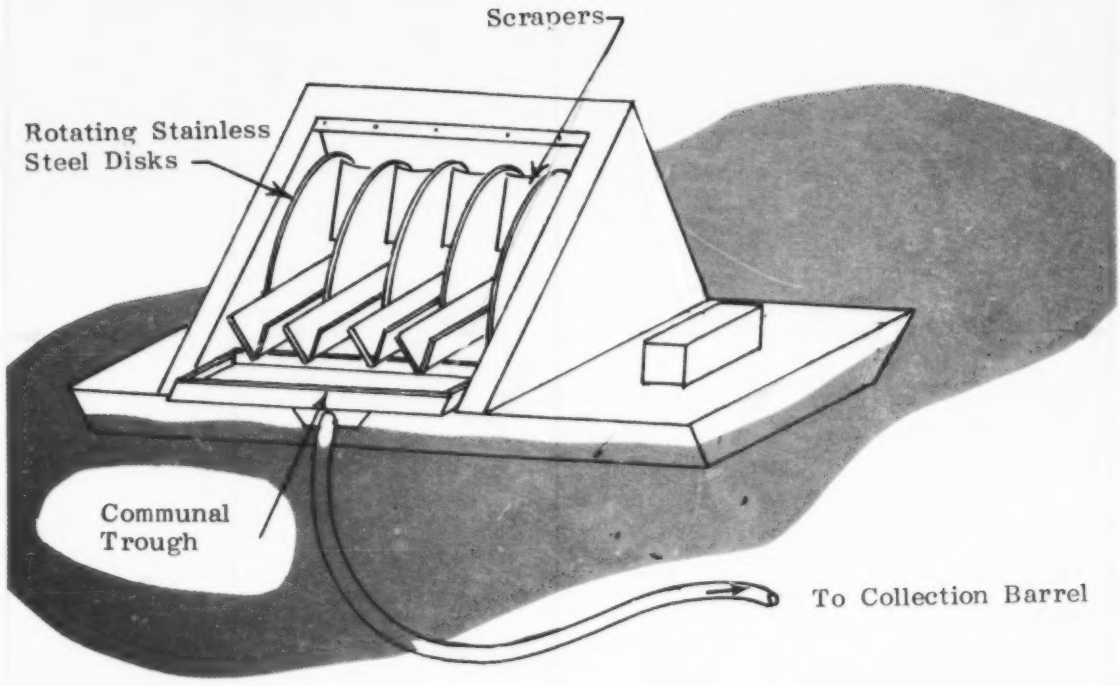


Figure 48. Line drawing of the Kebab 600. The 12-kg skimmer could positioned by one man without difficulty. It came with a remote disk speed controller, hand-operated pump, and floating reservoir, which are not shown.

Conclusions

The Kebab 600 could be used in oil spill applications, but is restricted by the designed low recovery rate and would only be used to its fullest capacity in small contained spills. A better application of a skimmer of this size and capacity could be water effluent quality control. Obvious examples of this type of application include removing oil from gravity-type separators or lagoon settling ponds.

The Kebab 600 is capable of operating without personnel in attendance. This will require a non-manually operated pump. An electric pump in a timed servo-cycle or a sensing probe of some sort would work well if a more readily usable holding reservoir is established. Continuous pumping or simple gravity overflow are simple solutions for industrial applications but do not lend themselves to spill applications.

The common trough may be placed in one of two positions depending on whether the collected oil is to be pumped or gravity discharged. When in the pumping position, the wipers are not physically long enough to scrape the entire surface of the disk. The outside surface of the disk on each end is not scraped. Both of these problems should be remedied.

Although wave testing was not as complete as calm water testing, the wave tests generally produced results of equal or better value for the oil recovery rate (ORR) and slightly lower recovery efficiency (RE) values. When the Kebab 600 faces oncoming waves the collection trough acts similar to a weir.

The minimal storage capacity of the floating reservoir is self-defeating. If the concept of local storage is continued, reservoir stability must be addressed. The reservoir was not found to be useful during the tests.

The hand pump does not supply the necessary head for high viscosity oil pumping. It does, however, supply sufficient power to pump water the required height. In these tests, the hand pump could not transfer the collected oil through the 1-m lift from the water level to the east washpad.

ORR increases with disk speed. Apparently, a minimum of about 20 rpm is necessary for effective collection in light oil. The ORR is higher in heavy oil than in light, but the RE is better in light than heavy. The Kebab 600 develops sufficient surface current to draw nearby oil to itself.

Recommendations

The Teflon wipers should be extended. The outer 7 mm of each disk that is left unscraped in the pumping position could be effectively used by simply lengthening the wipers. If a scraper is added for the outside of the end disks, an additional 25% of the available surface area could be utilized for oil collection.

Test Procedures

The main bridge and auxiliary bridge were positioned such that the associated booms formed a rectangular area of 180 m^2. Oil was pumped into the confined area to give a theoretically determined slick thickness of heavy or light oil. The Kebab 600 was started and allowed to operate at one of four settings on the variable-speed control knob. The settings were arbitrarily chosen to be every second mark on the dial.

The Kebab 600 was tested in slicks of light and heavy oil, and in calm water and in a 0.19-m wave, with disk rotational speed being the principal test variable. The wave was to have been a harbor chop. The wave did not, however, develop into a typical OHMSETT harbor chop wave, possibly because of the dampening by the two booms, which reduced the incident wave height at the north wall. The wave is better described as a non-uniform regular wave.

The Kebab 600 was allowed to operate for 20 to 30 minutes when the pump was stopped. A Wilden air-operated, double-acting diaphragm pump was used to remove the collected oil. Even at the slow pump setting used, the capacity of the Wilden greatly surpassed the capacity of the Kebab. The pump effectively kept the communal trough dry. The pump discharged into a $0.5m^3$ polypropylene barrel. A stopwatch was used to measure the oil calibration time. After the pump was stopped, the height of the fluid in the barrel was measured, and the fluid sampled to determine the relative amounts of oil and water collected.

This procedure was followed for all tests with the exception of the emulsion tests. For these tests, a 1.9 m^3 barrel received a 10-mm slick of heavy oil. The oil was emulsified with salt water using a high volume, low pressure air sparger. The sparger operated for 20 minutes prior to the start of the test to ensure that a through mixing of the oil and water had been accomplished. The Kebab 600 was then positioned in the barrel and operated as above.

Results

The test plans called for slick thickness to be an independent test variable. A variable westerly wind blew during testing, making control of the slick impossible in this test configuration. Local thinning of the slick further complicated the problem of consistent slick thickness. Measurements of slick thickness were made three different ways. The measurements were contradictory and serve only to cloud the issue further. Estimated slick thicknesses are listed with the other test results in Table 8, but no conclusions are drawn. These values are based on a percent-area-covered basis and may be incorrect.

The Kebab 600 generally provided a higher ORR in slicks of heavy oil. The oil adhering to the collection disks was visibly thicker with heavy oil, providing a greater volume of collected oil. The Kebab 600 achieves a superior RE in light oil.

The Kebab 600 generally provided higher ORR and lower RE in the wave tests. During wave tests, the collection trough acted as an overflow weir. This combined with the pump oversizing provided that both the oil and water caught by the trough in the wave tests was quickly evacuated from the trough. As the fluid that splashed into the trough included both oil and water, the oil recovery rate increases while the recovery efficiency decreases.

The only clear-cut result of the tests completed with intentionally emulsified oil is that emulsion will wet the stainless-steel disks. The surface currents produced by the Kebab 600 appear to be more substantial, but this may be more a result of the smaller oil covered surface area used for these tests than the emulsification.

The rate of rotation of the disk was treated as the principal independent test variable for both light and heavy oil and has been used as the absissae for the summary

TABLE 8. SUMMARY OF TEST RESULTS

Comment	Oil type	Speed (rpm)	Thickness (mm)	RE (%)	ORR (lph)
Calm water	Heavy	3.8	10	84	82
		4.3	10	95	180
		5.5	7	93	68
		16	8	43	78
		30	10	61	168
0.19 m wave	Heavy	3.5	17	89	129
		6.5	20	66	249
		7.0	15	62*	253
		21	15	76	432
		40	12	57	405
Calm water	Light	5.5	20	**	15
		7.0	13	**	14
		9.5	30	78	27
		10.5	10	**	2
		13	10	**	14
		25	7	86	75
		30	10	98	120
		40	9	99	252
		47	7	93	126
0.19 m wave	Light	24	7.5	97	126
		45	13	96	148
Emulsion	Heavy	3.5	10	E	52/99
		16	10	E	72/174
		16	5	E	62/142

*Kebab 600 capsized - 10 min 11 sec into the test, RE is based only on the height remaining after stripping.

**Volume collected was too small to sample adequately on these tests. RE is not available, and ORR assumes no water was collected.

E-emulsion tests - RE is not applicable. The ORR is split into (a) oil-only recovery rate and (b) fluid recovery rate on a no-additional-water-pick-up basis (tabulated as a/b).

of results. The recovery efficiency was typically above 80% in the light oil tests (see Figure 49) and between 60% and 80% in the heavy oil tests (Figure 50). RE for heavy oil peaks at 99+% at very low rpm. The ORR generally increases with rpm. Interestingly, a minimum effective speed of approximately 20 rpm is clearly necessary for slicks of light oil as seen in Figure 51. The maximum oil recovery rate obtained was 432 liters per hour in a slick of heavy oil with the Kebab 600 operating at 21 rpm in waves (see Figure 52). A maximum oil recovery rate of 252 liters an hour was obtained with light oil at 40 rpm prior to a significant decline to 126 lph at 47 rpm as seen in Figure 51. It is believed that at the higher rotational speed the low viscosity oil is literally thrown from the disks because of the lack of adhesion and centripetal force.

WYLIE SKIMMER

The Wylie Skimmer (shown in Figure 53) is constructed of spare parts with minimal capital investment. The skimmer is primarily a wooden structure which uses 55-gallon drums for flotation. The device successfully withstood 2 knots runs without mishap. The device was designed around a road-legal trailer and was sufficiently mobile to be towed cross-country from British Columbia to New Jersey. The unit is designed to be a floating barge with an interior holding tank for preliminary oil/water separation. The tank is rectangular and has an open top and bottom. The collected fluid is intended to be of very high water content with free water separation. An electric trolling motor was used as a low pressure pump to minimize the mixing of oil and water.

The skimmer is planned to collect oil trapped by a boom. The fluid is to pass from surface to separation tank through a 203-mm (8-inch) stove pipe and flexible hose network which will induce a counterclockwise current in the separation tank. The intake to the pipe-hose network was simply a length of stove pipe mounted on a semi-circular wooden float. The inventor, Mr. M.M. Wylie, of British Columbia served as on-site technical consultant throughout the test series.

Conclusions and Recommendations

The tests are conclusive. The device is not able to collect oil from the water surface. Because of the OHMSETT modifications the device was able to collect minimal amounts of fluids, but the as-built model was incapable of collection in anything but the mildest of test conditions. The wooden float that supported the suction hose formed a clear water area 60% to 70% of the available oil-collecting area at the pipe. If a means of oil removal from the water surface is developed, the skimmer will be limited to the working speed of booms in a catenary configuration. Three different mounting systems for the floating intake were used. Each of these is shown in Figure 54.

Tests were run during which the separation tank was precharged with approximately 1 m^3 of oil. These were run to find the maximum towing speed of the device when operating if it were not boom limited. At 1.5 knot there was a large flow of oil drawn from the separation tank. The out-the-bottom loss diminished as the tow speed was decreased down to the critical speed of about 1 knot. These tests were run with no attempt at further collection. The device losses through this mechanism increase when additional oil collection is attempted. Losses were apparent at 0.25 knot, with additional collection.

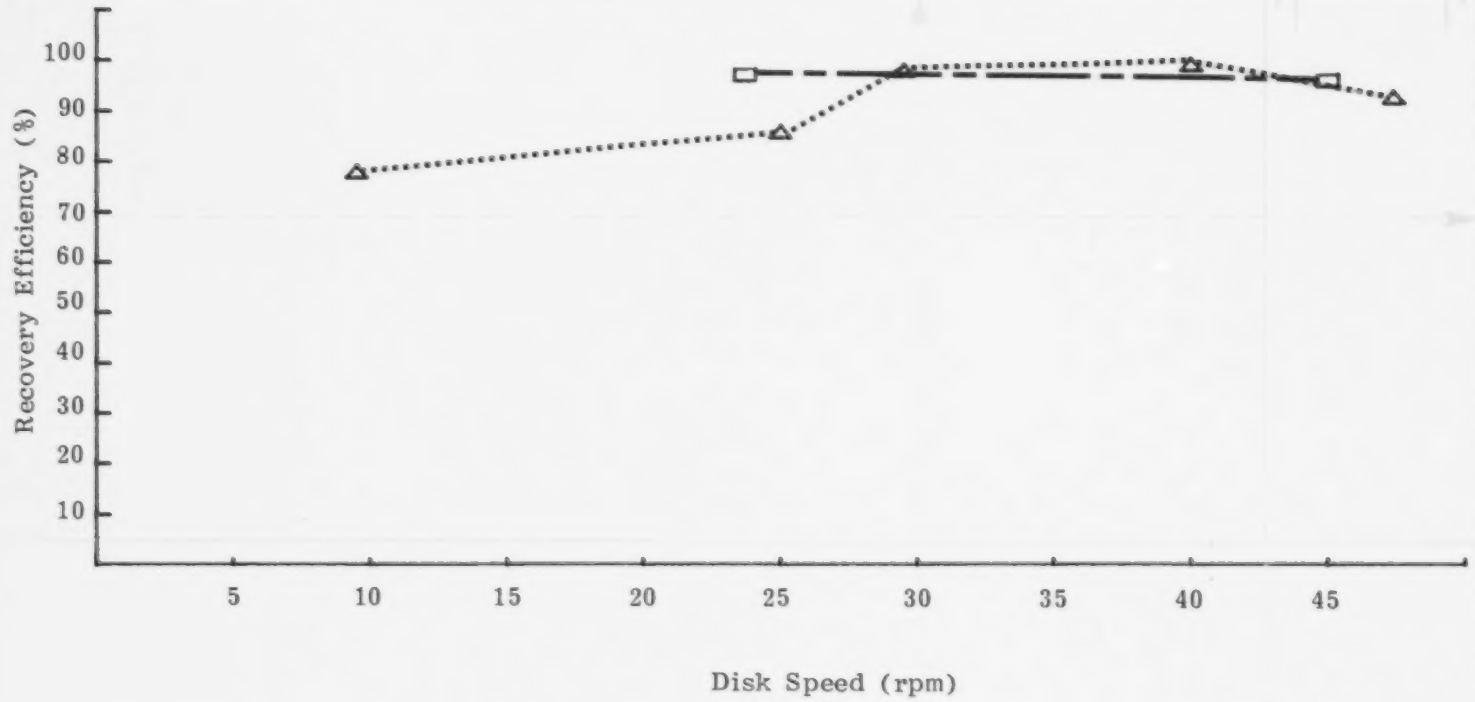


Figure 49. Recovery Efficiency of the Kebab 600 in calm water and in the 0.19-m wave using light oil.

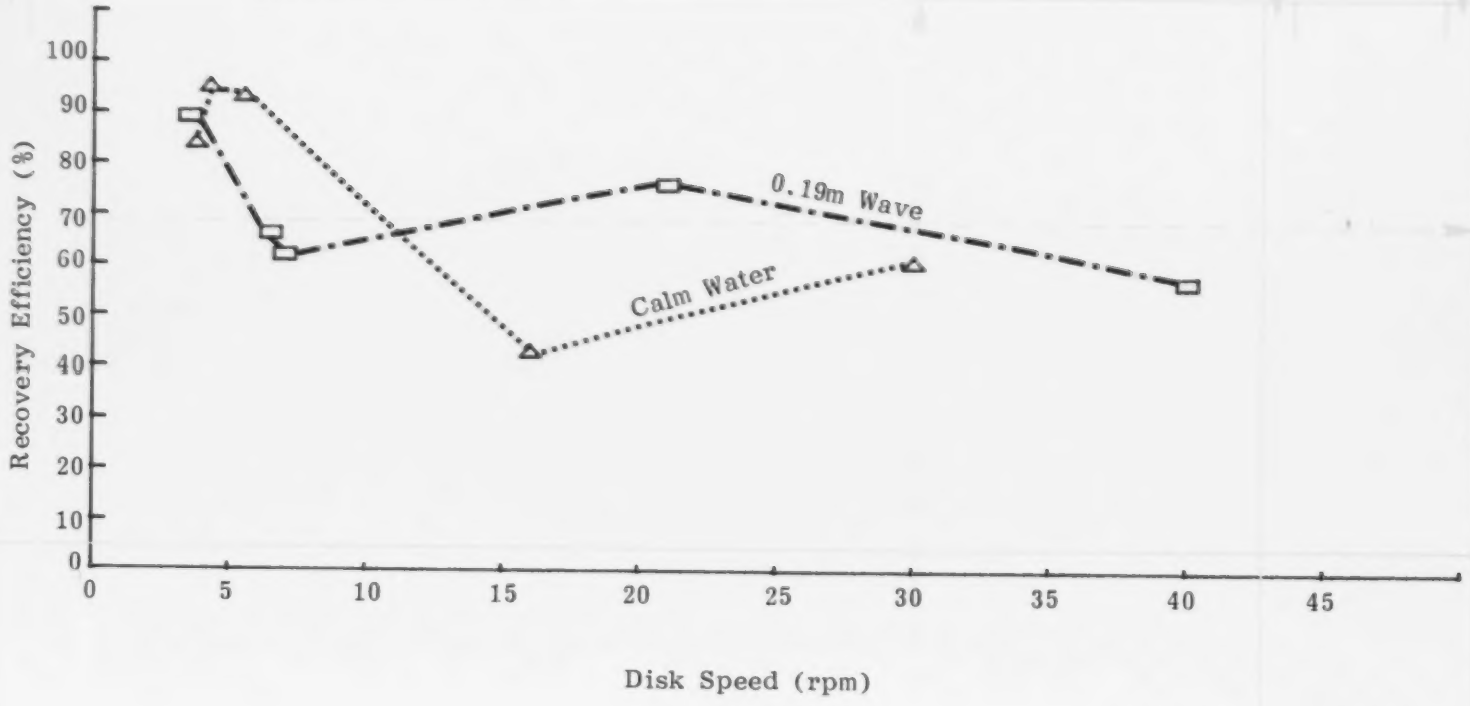


Figure 50. Recovery Efficiency of the Kebab 600 in slicks of heavy oil.

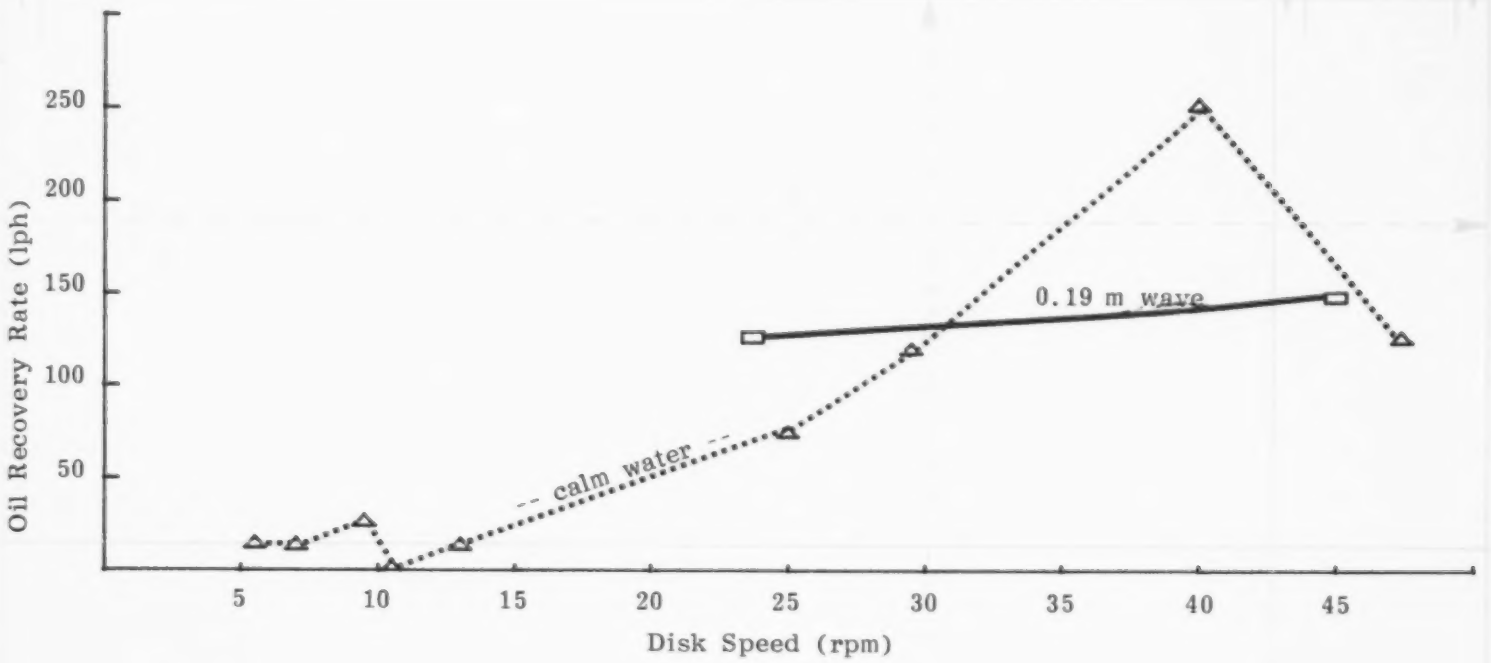


Figure 51. Oil Recovery Rate of the Kebab 600 versus disk speed. The drop-off at 40 rpm is thought to be caused by the lack of adhesion of the oil to provide centripetal forces. These tests were run with slicks of light oil.

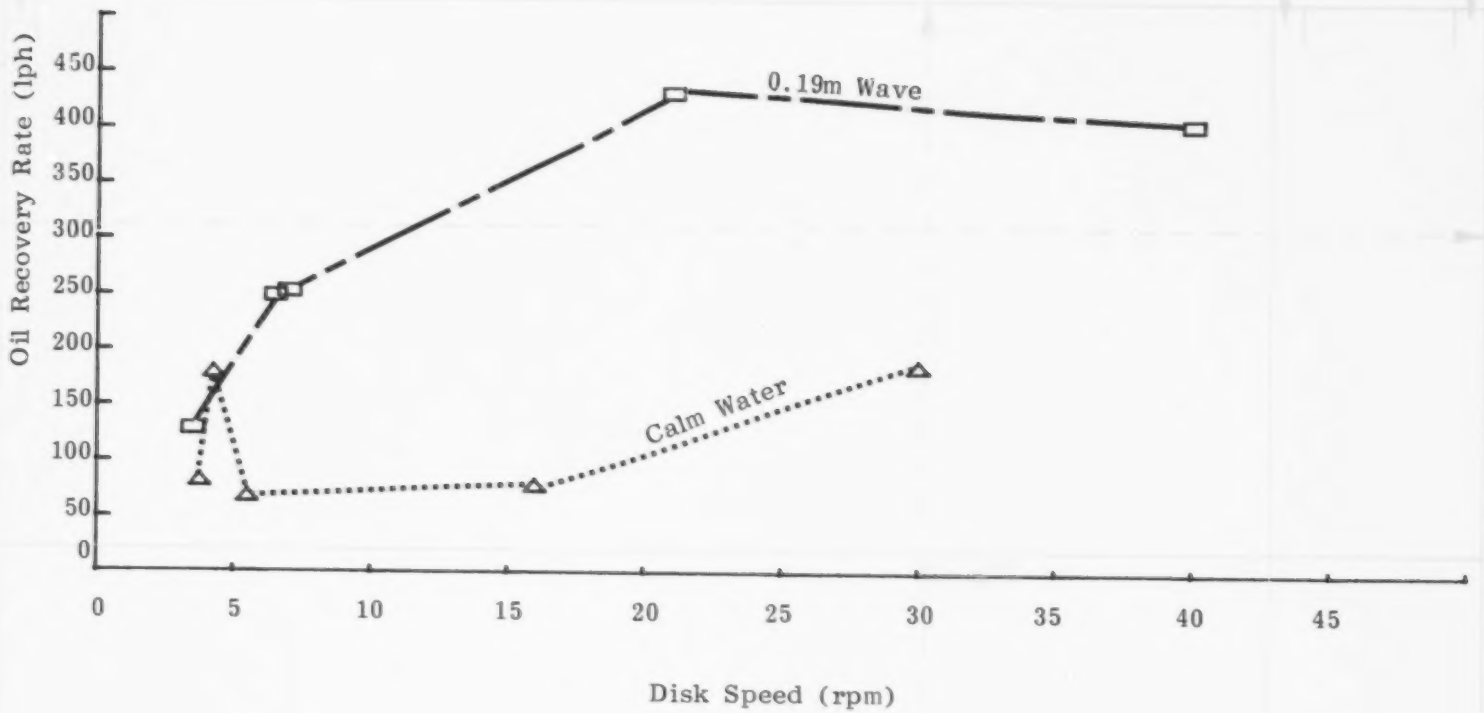


Figure 52. Oil Recovery Rate of the Kebab 600 in slicks of heavy oil. The higher Recovery Rate in the wave is caused by splash-over into the trough.

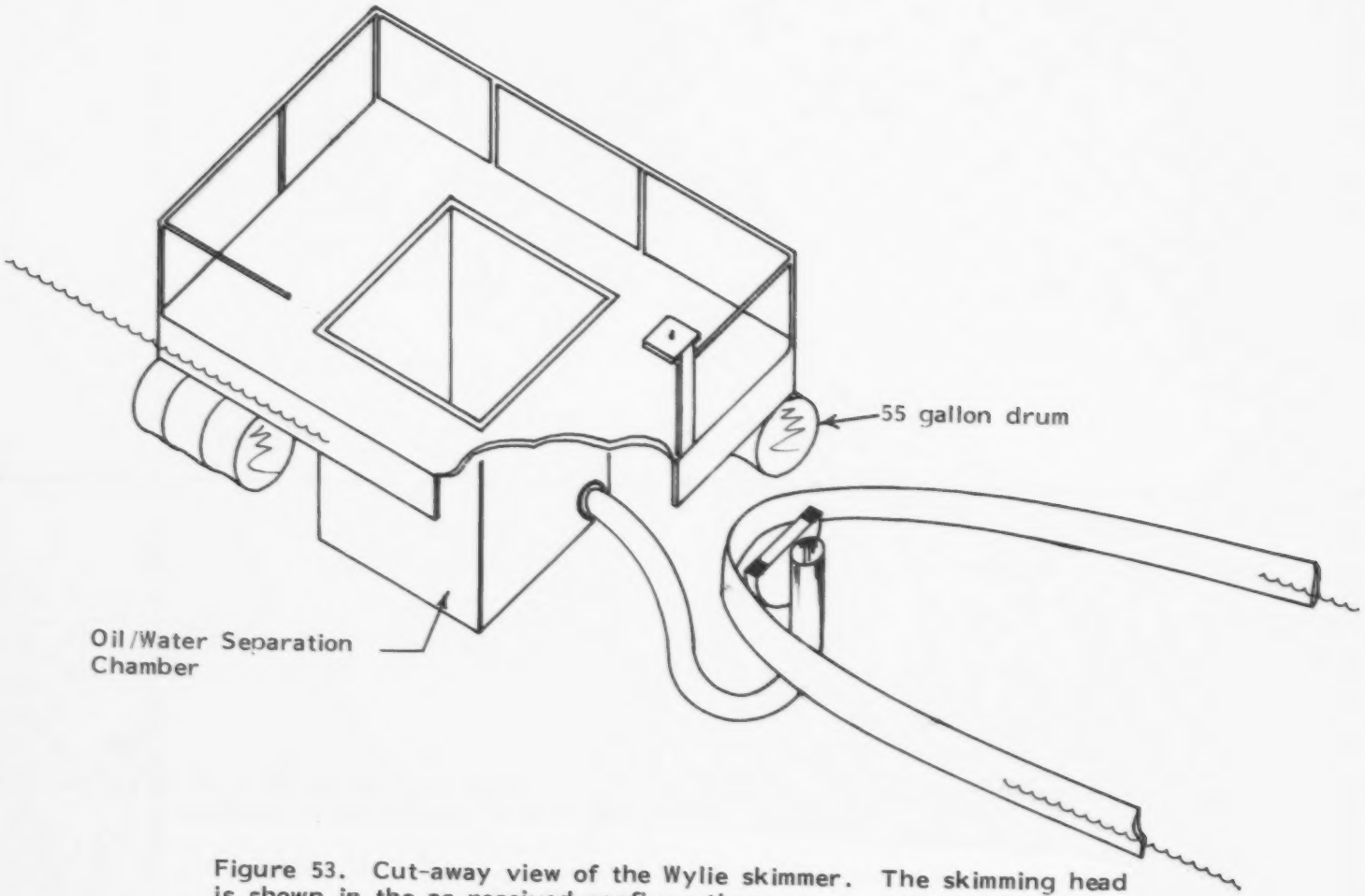


Figure 53. Cut-away view of the Wylie skimmer. The skimming head is shown in the as-received configuration.

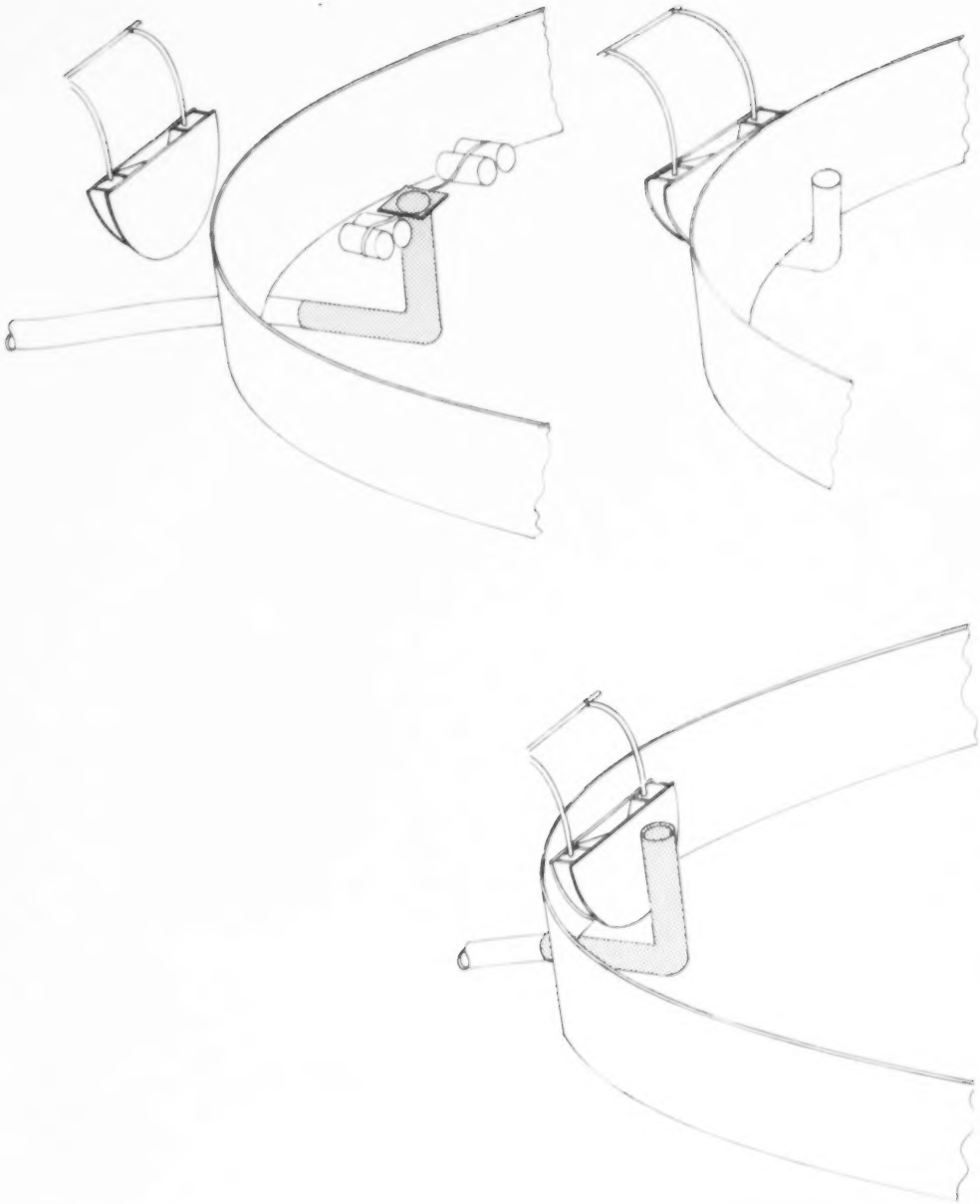


Figure 54. The Wylie skimmer is based on a boom-assisted oil collection head. The three configurations used during the testing are shown. These were tried in a counterclockwise order beginning with the set-up shown in the lower right.

Test Procedures

Originally, a series of calm water and wave tow tests was planned from 0.25 knot to 1.0 knot as the boom limitation was recognized. The plan and matrix were abandoned after the first day of testing when difficulties become apparent. When OHMSETT modifications were obviously inadequate, the full capabilities of the test crew and support personnel were placed at Mr. Wylie's disposal. Unhampered by manpower or material problems, Mr. Wylie was not successful in his attempts to modify the skimmer.

During the calm water tests, the oil that the Wylie skimmer had collected and stored in the onboard separation chamber was transferred to the auxiliary bridge recovery tanks using a Kaiser stationary skimmer. This oil was measured and sampled for later analyses.

Results

Eleven usable tests were run over four tank days, including three repeats. In calm water, the skimmer typically collected 20% to 40% of the encountered oil. The Wylie/Kaiser combination gave 15% to 25% oil in the recovered fluid (RE) at a rate of 0.5 to 1.5 m^3/hr (ORR). The fluid in the auxiliary bridge tanks remaining after stripping was above 80% oil which is probably closer to the RE of the skimmer. The skimmer did not give sufficient recovery in any waves to measure. These results are taken as zero.

SKIM-PAK CLUSTER

The Skim-Pak skimming weir was tested at OHMSETT in 1978 under OITC sponsorship (JO 46-3). These tests led to minor modifications in the skimming head. The skimming heads (shown in Figure 55) in the cluster were constructed of molded fiberglass. Each head is rectangular with two tines straddling a self adjusting flap, which serves as a weir. The flap is intended to allow high oil-content fluid to be collected. The skimmed oil is transferred through a 38-mm (1½-inch) diameter hose 3 m in length. These hoses are joined at a common cylindrical manifold approximately 1 m in diameter and 0.25 m in height (shown in Figure 56). A 76-mm-diameter (3-inch) PVC hose connection is located at the center of the bottom of the manifold for discharge.

The unit tested was a prototype developed and provided by Douglas Engineering of Concord, California. Mr. Douglas Gore served as the technical representative and remained on site throughout most of the testing.

Conclusions

The Skim-Pak cluster produces a higher Oil Recovery Rate (ORR) than a single skimming head, but not in proportion to the number of heads.

The 1978 test program showed that the skimming heads are much more effective when attended with a control wand than when free floating. These tests show similar results when compared on a per head basis. The recovery efficiency cannot be maintained since the multiple heads cannot be tended as the single head. Wave conformance was excellent. No diving or porpoising was observed in the waves

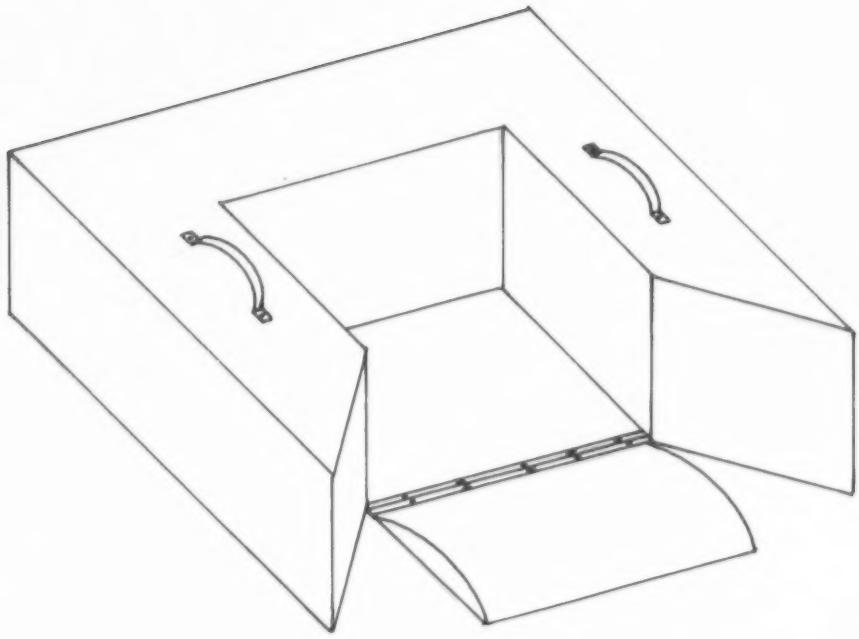


Figure 55. The Skim-Pak skimming head. The flap, shown extended here, is generally within the tines of the head. The oil overflows this weir and is evacuated from the bottom of the head.

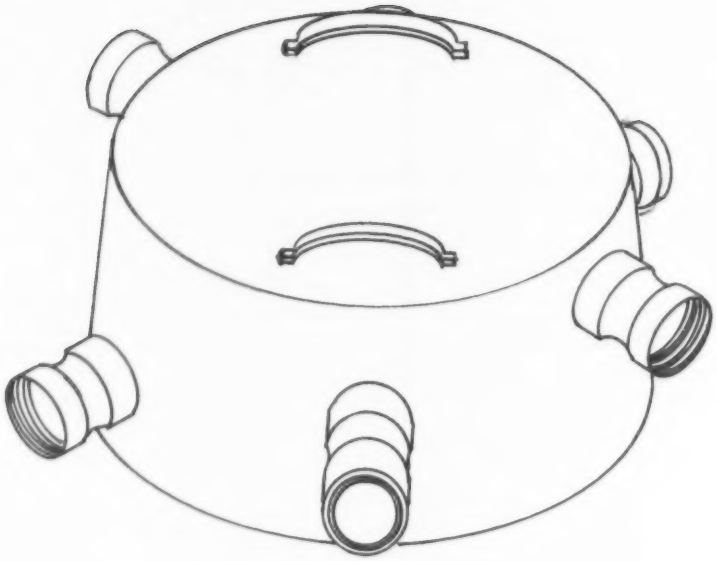


Figure 56. The Skim-Pak manifold was approximately 1-m in diameter. Each of the camlock fittings was coupled to a skimming head with a 3-m long, 38-mm diameter hose.

tested. A clear-water problem did, however, occur. The yawing of individual heads created oil-free patches on the water surface.

Inclement weather conditions hampered the testing. Only thirteen tests were conducted over the four day period. Ice formation within the manifold proved to be a severe problem. This ice could not be freed by simply alternating the flow direction from the pump.

The assembled cluster was difficult to maneuver. The required facilities could not be expected to be available on boats for at-sea deployment. The fragileness of the unit and the multiple hoses would prevent throwing the cluster overboard for deployment. Field deployment would probably require a man at water level or physically in the water.

Recommendations

The Skim-Pak cluster needs a more secure mounting for the attachment of the 76-mm discharge hose. The attachment for this unit was made with only the fiberglass manifold coating material. A good glue should be used to secure the connection. This may well have been an oversight caused by the rush to produce a prototype for testing.

The camlock connections at the manifold should be kept as an integral part of the design. This permits quickly changing the number of floating heads to any number up to six. The plastic fittings should be improved, as they are readily broken. Either a higher quality plastic or metal camlocks, if weight is not a prime consideration, should be substituted.

Hoses should not be shipped or stored in coils. These hoses tended to retain their coil despite the efforts to straighten them. The substitution of lightweight tubing to prevent the heads from striking the manifold should also be considered. This will undoubtedly affect the device's existing wave conformance, but some tradeoff must be made.

A step-by-step, systematic, simple deployment plan must be developed if the device is to be deployed in any open water application.

Test Procedure

The skimmer was positioned in the extreme North end of the tank. The two center beach sections were lowered and locked into position to provide sufficient space for the heads as shown in Figure 57. Circo X medium oil was pumped into the space bounded by the tank walls and the auxiliary bridge boom. The volume of oil and the surface area were used to determine a theoretical slick thickness. This procedure was followed for the device with five and six heads. An OHMSETT air-operated, double-diaphragm pump was placed on the auxiliary bridge. The discharge was routed to an auxiliary bridge recovery tank for measurement and sampling.

One head was connected to an OHMSETT pump discharging to a 1.9 m^3 (500 gal) polyethylene cylindrical tank for measurement and sampling for the single head tests.

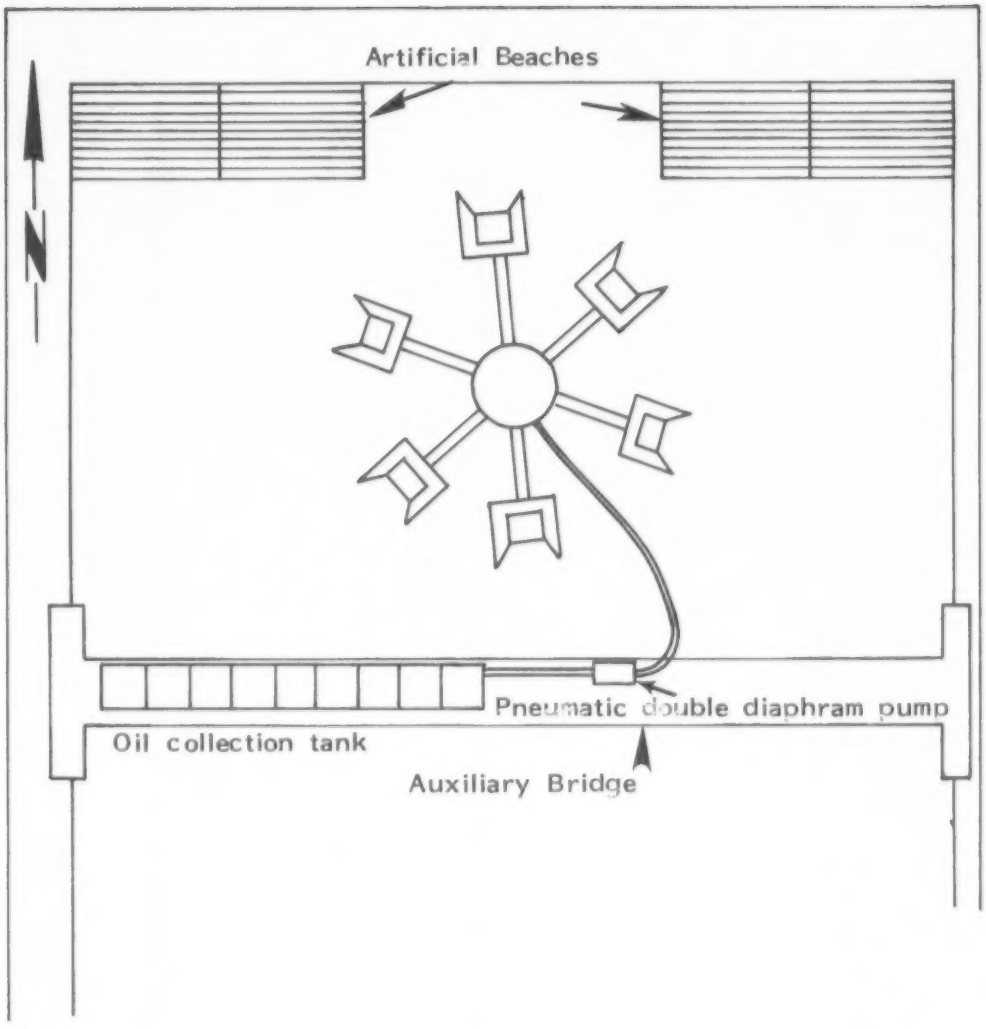


Figure 57. Test set-up for the Skim-Pak cluster. The two center artificial beach sections were lowered for this testing. The postive-displacement pump on the auxiliary bridge transferred the oil and water collected to the tanks for sampling and measurement.

Results

The device provided test data when used in the one, five, and six head mode. Only calm-water tests were run sufficiently often to draw firm conclusions. Short-term slick control was possible to some degree, but long-term control was not feasible.

Increasing the number of heads did not provide a proportional increase in oil recovery rates. The cluster oil recovery rate increases by a factor of 2.13 when going from one head to five heads in a 0.19 m x 2.79 m regular wave and approximately 16-mm slicks. The calm-water results in essentially equal slick thickness only increased by a factor of 1.88 over the wave test results.

When operating in a given mode and slick thickness, the results are consistent and waves appear to have little effect. In the thin slick (7 mm) the six headed cluster had an ORR of about 2.2 m^3/hr and 7% RE. In a thicker slick, the five-headed cluster had about 25% RE and a 7.7 m^3/hr ORR. Test-by-test summaries are listed in Table 9.

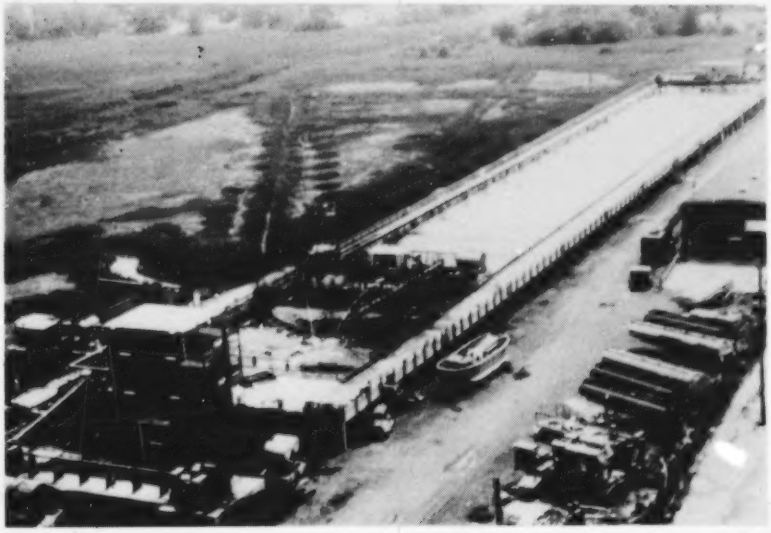
TABLE 9. SKIM-PAK CLUSTER TEST RESULTS

Number of skimming heads	Slick thickness (mm)	Waves (m x m)	RE (%)	ORR (m^3/hr)	ORR/N (m^3/hr/head)
6	7	calm	8	2.26	0.38
6	7	calm	7	2.19	0.37
6	7*	calm	10	3.04	0.51
6	7	0.26 x 6.24	7	2.00	0.33
1	25	calm	30	3.86	3.86
1	21	calm	31	4.14	4.14
1	20	0.26 x 6.24	31	3.46	3.46
1	23	0.19 x 2.79	24	2.93	2.93
1	15	0.19 x 19.22	25	3.53	3.53
5	17	calm	24	7.0i	1.40
5	15	calm	26	7.80	1.56
5	15*	calm	36	10.35	2.07
5	16	0.19 x 2.79	28	7.63	1.53

*Oil was pumped into the area at the estimated oil recovery rate determined in the process to minimize thinning of the slick.

APPENDIX A

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY



The U.S. Environmental Protection Agency operates the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) located in Leonardo, New Jersey. This facility provides an environmentally safe place to conduct testing and development of devices and techniques for the control and clean-up of oil and hazardous material spills.

The primary feature of the facility is a pile-supported, concrete tank with a water surface 203 meters long by 20 meters wide and with a water depth of 2.4 meters. The tank can be filled with fresh or salt water. The tank is spanned by a bridge capable of exerting a horizontal force up to 151 kilonewtons while towing floating equipment at speeds to 3.3 meters/second (6.5 knots) for at least 40 seconds. Slower speeds yield longer test runs. The towing bridge is equipped to lay oil or hazardous materials on the surface of the water several meters ahead of the device being tested, so that reproducible thicknesses and widths of the test slicks can be achieved with minimum interference by wind.

The principal systems of the tank include a wave generator, a beach, and a filter system. The wave generator and absorber beach can produce regular waves to 0.6 meter high and to 45 meters long, as well as a series of 0.7 meters high reflecting, complex waves meant to simulate the water surface of a harbor. The tank water is clarified by recirculation through a 628 cubic meter/hour diatomaceous earth filter system to permit full use of a sophisticated underwater photography and video imagery system and to remove the hydrocarbons that enter the tank water as a result of testing. The towing bridge has a built-in oil barrier which is used to skim oil to the North end of the tank for cleanup and recycling.

When the tank must be emptied for maintenance purposes, the entire water volume of 9800 cubic meters is filtered and treated until it meets all applicable State and Federal water quality standards before being discharged. Additional specialized treatment may be used whenever hazardous materials are used for tests.

Testing at the facility is served from a 650 square meters building adjacent to the tank. This building houses offices, a quality control laboratory (which is very important since test fluids and tank water are both recycled), a small machine shop, and an equipment preparation area.

This government-owned, contractor-operated facility is available for testing purposes on a cost-reimbursable basis. The operating contractor, Mason & Hanger-Silas Mason Co., Inc., provides a permanent staff of twenty-one multi-disciplinary personnel. The U.S. Environmental Protection Agency provides expertise in the area of spill control technology and overall project direction.

For additional information, contact: Richard A. Griffiths, OHMSETT Project Officer, U.S. Environmental Protection Agency, Research and Development, MERL, Edison, New Jersey 08837. Telephone: 201-321-6629.

APPENDIX B

OHMSETT OIL DISTRIBUTION SYSTEM

The main bridge oil distribution system is designed to contain 11.4 m^3 of test oil, which can be distributed from the moving birdge directly in front of any advancing oil, skimmer which will fit within the confines of the 19.8-m tank width. The distribution system consists of two major categories: the pump/meter section (see Figure B-1), and the manifold system (see Figure B-2).

Each oil distribution pump is fitted with complete bypass piping so that any pump or combination of pumps can be used to distribute oil. The two oil storage tanks are internally divided into two sections. Each section contains a 5 kW electric heater. These heaters are used to maintain a sufficiently high oil temperature so that the oil distribution pumps are not viscosity limited. It has been shown that the oil reaches water temperature virtually instantly upon contact.

Pump Station No. 1

This positive-displacement, progressive-cavity pump is generally used only when very low oil distribution rates are desired. The pump is model 1L10 manufactured by Moyno. The driver is an electric, 230-V, 3-phase motor rated at 3.73 kW.

Pump Station No. 2

This pump is generally not used. The positive-displacement, progressive-cavity pump model 1L10H is manufactured by Moyno. The pump is driven by an 1170-rpm, 230-V, 3-phase electric motor. The pump speed is reduced to 370 rpm using pulleys. The motor is rated at 5.60 kW.

Pump Station No. 3

This is the most commonly used pump in the oil distribution system. It is a positive-displacement, progressive-cavity pump; model SWG88 manufactured by Moyno. It is driven by a 3-phase, 230-V, 1180-rpm electric motor rated at 18.65 kW. The pump speed is reduced to 373 rpm using pulleys.

Pump Station No. 4

This vertical, centrifugal pump is used when low-viscosity oil is distributed at high volumetric rates. The pump is model 5443B-28, manufactured by Fairbanks Morse. It is driven by a 230-V, 3-phase, 1750-rpm electric motor rated at 14.92 kW.

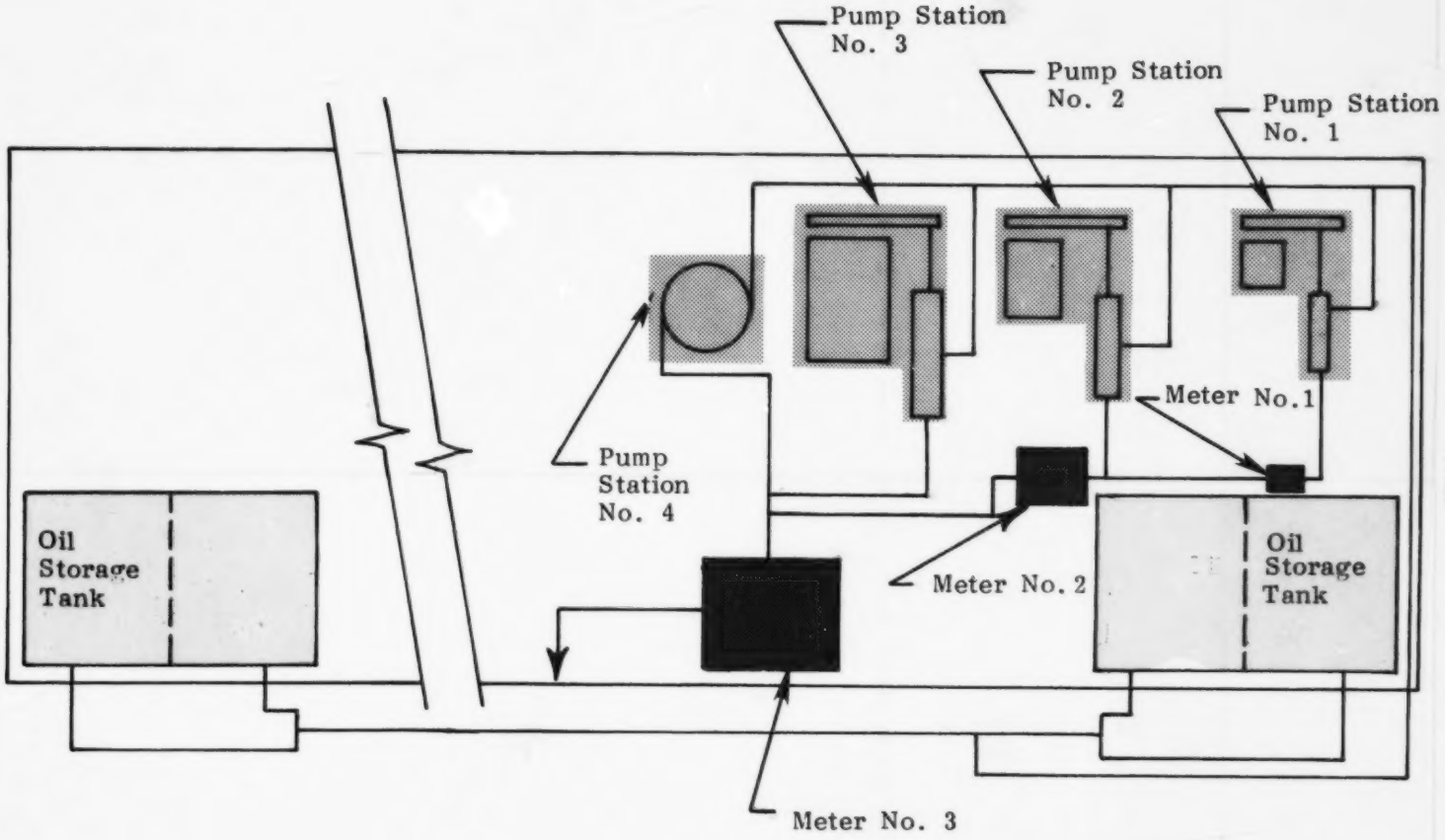
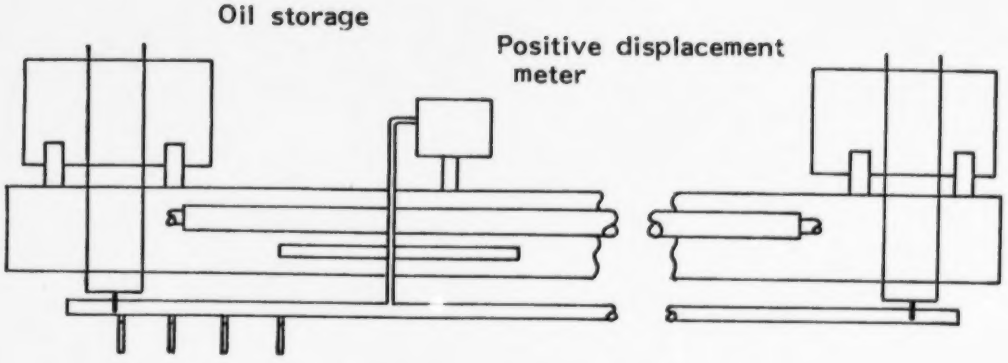
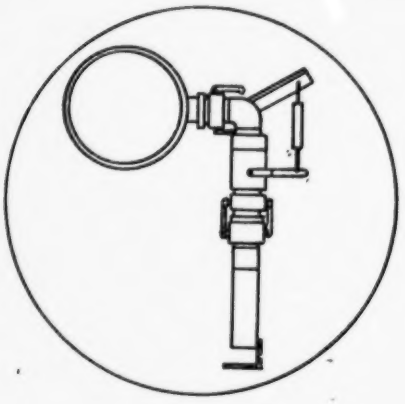


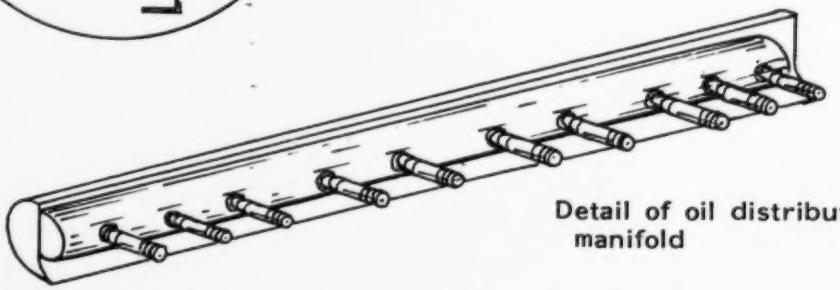
Figure B-1. This plan-view of the Main Bridge is not drawn to scale to avoid confusion. Each of the pump and metering stations is described within Appendix B.



View of Main Bridge looking North



Detail of oil distribution nozzles



Detail of oil distribution manifold

Figure B-2. The South side of the OHMSETT Main Bridge holds the oil distribution manifolds. The most often used systems are shown in separate drawings immediately above: spray nozzles in the circled detail, and the 4.6-m long manifold built from a 152-mm diameter pipe.

Meter No. 1

This 52-mm positive displacement meter is manufactured by Brodie (serial number 174812).

Meter No. 2

This is a 76-mm positive displacement meter, model 441, manufactured by Neptune.

Meter No. 3

This meter is in line with all pumping stations. It is used to quantify the oil distribution. It is a positive-displacement meter model 2415-60-SF-2 manufactured by Tokheim.

Manifold No. 1

A 152-mm pipe with 20 equally spaced 51-mm camlock fittings that can be equipped with a distribution nozzle or be capped to prevent overflow. This feature can be combined with water jets to create a slick of any desired width arbitrarily positioned across the test tank.

Each nozzle contains a pneumatically actuated valve controlled from the main bridge at pump station 3.

Manifold No. 2

A 152-mm pipe 4.6 m long has been cut and baffled to create an overflow weir. Oil is fed to this weir from the nozzles on weir no. 1. The pneumatic controls for manifold no. 1, also control the flow of oil from this manifold.

Manifold No. 3

This 254-mm weir is similar in construction to manifold no. 2. The 10.7-m long manifold is used when exceptionally high flow rates or volumes would make distribution from the main bridge impractical. This manifold has no direct connection to the main bridge oil distribution pumps or oil storage. It is supplied oil from an oil tanker equipped with its own pump.